

The Effect of the Cam Deformity on the Insertion of the Femoral Component in Hip Resurfacing

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Abstract: Surface arthroplasty simulations were generated using 3-dimensional computed tomographic scans from 61 consecutive patients presenting with idiopathic osteoarthritis to evaluate the change in femoral component positioning that would allow optimal alignment when resurfacing a cam-type deformity. Anatomical parameters were measured to quantify the influence of the deformity on the insertion technique of the femoral implant. A modified femoral head ratio was initially calculated from plain radiographs to define the severity of cam deformity in these patients. A severe deformity required more superior translation of the entry point and greater reaming depth to allow safe insertion with optimal implant alignment. This could be achieved while preserving the leg length, minimizing the component size, and maximizing the amount of host bone contact, although the horizontal femoral offset was reduced. These findings suggest that the femoral component can be safely inserted by modifying the surgical technique despite progressive deformity of the femoral head. **Keywords:** hip resurfacing, cam deformity, surgical technique, femoral implant, computed tomography simulation, femoral head ratio.
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The newer generation hybrid surface arthroplasty is becoming an increasingly popular alternative to conventional total hip arthroplasty in young patients having osteoarthritis. Modern metal-on-metal resurfacings have shown good short-term functional results along with high survival rates [1-6]. The longevity of surface arthroplasty is affected by careful patient selection, the quality and deformity of the bone, as well as the implant design and positioning. An improper orientation of the femoral component has been associated with early failures from femoral neck fractures and aseptic loosening [1,7,8]. It is generally recommended to insert the femoral component in relative valgus alignment and completely seat the implant to cover all reamed cancellous bone while avoiding notching the super-

olateral femoral neck [1,7-13]. However, obtaining optimal implant positioning is often difficult with progressive deformity of the femoral head.

Surface arthroplasty is performed for numerous causes of primary and secondary osteoarthritis. The cam-type deformity, also known as the *pistol grip deformity* when visualized on an anteroposterior (AP) radiograph, is one of the most common bony abnormalities of the femoral head encountered at the time of resurfacing. The deformity occurs at the junction of the head and neck resulting in loss of sphericity of the femoral head, a varus tilt, short neck length, and a decrease in anterior femoral head-neck offset [14-18]. Cam deformity is believed to arise from mild subclinical developmental abnormalities [15-17,19,20]. The prevalence of this deformity is reported to be as high as 40% in patients presenting with idiopathic osteoarthritis and occurs predominantly in men [16,17,19,20]. It is essential to recognize the abnormal relationship between the femoral head and neck at the time of resurfacing as this will require adjustments in the positioning of the femoral component to safely achieve optimal alignment.

Adequate bone in the femoral head and neck is a prerequisite in ensuring the survival of a surface arthroplasty. The cam deformity is particularly worrisome because severe flattening results in segmental bone loss, as opposed to the cavitory defects encountered with femoral head cysts. The superior flattening can predispose to varus malalignment or superior notching

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while attempting to insert the femoral component in relative valgus. This deformity can further lead to incomplete seating of the femoral component with exposed reamed cancellous bone. A proud component also increases the distance between the prepared femoral head and implant resulting in a thicker cement mantle. In the axial plane, the loss of anterior femoral head-neck offset can cause impingement with the acetabular component if not adequately corrected at the time of implant insertion [21]. Modifying the orientation of the femoral component to accommodate the abnormal shape of the femoral head will inevitably alter the final anatomical parameters, such as component size, femoral offset, and leg length, given the lack of implant modularity in resurfacing.

There currently exist no recommendations to guide orthopedic surgeons in managing femoral head defects during surface arthroplasty. The purpose of this study was to better understand how a cam deformity of the femoral head changes the positioning of the femoral component in hip resurfacing. We also sought to determine whether the femoral implant can be safely inserted with optimal alignment despite progressive deformity of the femoral head and neck. It is our belief that severe flattening and segmental bone loss would require greater superior translation of the starting point along the lateral femoral head and an increase in the reaming depth to allow insertion of the component in relative valgus without notching the femoral neck. Surface arthroplasty simulations were performed using 3-dimensional computed tomographic (CT) scans from patients presenting with idiopathic osteoarthritis to determine the change in femoral component positioning that would allow optimal implant alignment according to the severity of deformity. Anatomical parameters were then measured to quantify the influence of the cam deformity on the insertion technique of the femoral component. A modified femoral head ratio (FHR) was initially calculated from plain radiographs of each hip to define the severity of deformity in these patients.

Materials and Methods

The radiographs and CT scans were reviewed from 61 consecutive patients (66 hips) with complete imaging who presented with idiopathic osteoarthritis before undergoing hip resurfacing. There were 47 men and 14 women, with a mean age of 50.3 years (range, 33-63 years). All patients had a preoperative AP radiograph of the hip, frog lateral radiograph, and CT scan with 3-dimensional reconstruction. A modified FHR was calculated from the AP radiographs to quantify the femoral head deformity [16]. Specific radiographic parameters from both the AP and lateral views were then used to correlate the radiologic findings that would be expected with worsening cam deformity.

The modified FHR measures the portions of the head located above and below the femoral neck axis [16]. The femoral neck axis is a line through the middle of the neck on an AP radiograph, irrespective of the center of the head, and extended proximally into the femoral head. It is drawn by joining 2 points in the neck: (1) the midpoint of the intertrochanteric line between the tip of the greater trochanter laterally and the most medial tip of the lesser trochanter and (2) the midpoint between the superior and inferior junction of the femoral head and neck. The lateral and medial portions of the femoral head were measured by using perpendicular lines on either side of the femoral neck axis to the most superior and inferior edge of the femoral head, respectively (Fig. 1). The modified FHR represents the superior distance over the inferior distance.

Radiographic parameters were assessed from the AP and frog lateral x-rays to determine whether the modified FHR is representative of a typical cam deformity. The AP radiographs were taken with the hips in 15° of internal rotation. The femoral neck-shaft angle was measured where the femoral neck axis intersects the anatomical axis of the femur, which is a line drawn parallel to the femoral diaphysis using 2

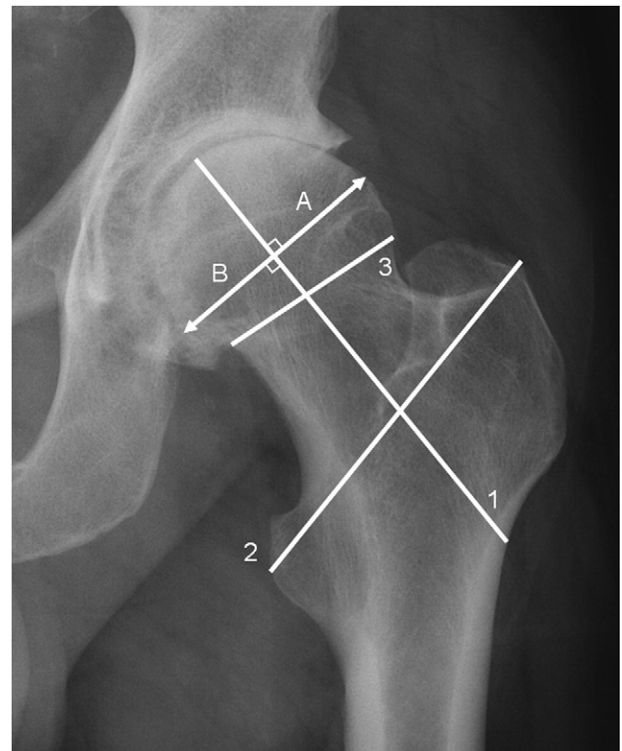


Fig. 1. Radiograph depicting the modified FHR: (1) femoral neck axis, (2) intertrochanteric line, (3) line extending from the superior to inferior junction of the femoral head and neck, (A) superior portion of the femoral head, and (B) inferior portion of the femoral head. The modified FHR was calculated by dividing the lateral over the medial femoral head ($FHR = A/B$).

separate points in the center of the intramedullary canal. The femoral neck length is the distance along the neck axis from the intertrochanteric line to the junction of the head and neck. A neck length ratio was calculated by dividing the femoral neck length over the entire length of the femoral neck axis from the lateral edge of the femoral cortex to the tip of the head to standardize for any error in magnification of the radiographs. The superior concavity at the head and neck junction was assessed using the superior angle. A superior tangent line was drawn parallel to the femoral neck axis such that it crosses the point where the head and neck intersect. The superior angle was formed by a second line extending from the head-neck junction to the widest point on the superior aspect of femoral head. An inferior angle was measured using the same method to evaluate the inferior concavity of the head and neck junction (Fig. 2).

The frog lateral radiographs were used to assess the anterior femoral head-neck offset ratio. The femoral head-neck offset ratio was measured using a standard technique although it was originally described with a cross-table lateral radiograph [14].

A surface arthroplasty simulation was generated from each CT scan to measure the change in femoral implant positioning required to achieve ideal alignment despite

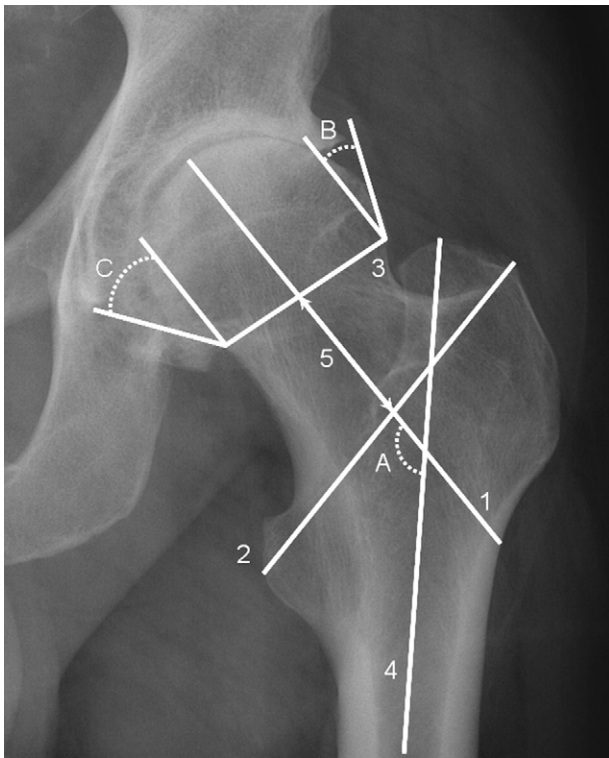


Fig. 2. Radiographic parameters: (1) femoral neck axis, (2) intertrochanteric line, (3) line extending from the superior to inferior junction of the femoral head and neck, (4) anatomical axis of the femur, (5) femoral neck length, (A) femoral neck-shaft angle, (B) superior angle, and (C) inferior angle.

progressive deformity of the femoral head and neck. Anatomical parameters were then calculated to determine the influence of the cam deformity on the insertion of the femoral implant. The optimal component orientation was defined as the position that would allow as much valgus as possible in the coronal plane, until a maximum of 10° relative valgus, without any notching and completely seating the implant covering all reamed femoral bone. Secondary objectives were to maintain horizontal femoral offset and leg length, minimize the femoral component size, and limit the distance between the femoral head and implant by modifying the reaming depth to obtain a cement mantle less than 2 mm. The translation and version of the femoral component in the axial plane was determined by maximizing the amount of host bone contact with the prosthesis while correcting the anterior femoral head-neck offset without notching.

From the simulations, the amount of relative valgus of the femoral component was calculated by subtracting the femoral neck-shaft angle from the stem-shaft angle. The center of rotation about which valgus orientation was achieved corresponded to a point along the femoral neck axis at the junction of the head and neck. This axis of rotation was chosen because it is just distal to where the deformity occurs in the femoral head. A point more proximal along the femoral neck axis would result in a greater likelihood of notching, whereas a point more distal would require greater translation along the femoral head reducing the horizontal femoral offset. The superior translation was measured in the coronal plane from the neutral entry point where the femoral neck axis exits medially at the apex of the head. The smallest femoral implant diameter was chosen to accommodate optimal positioning to preserve acetabular bone stock. The component-head size difference was obtained by subtracting the diameter of the femoral head from that of the implant. Limb length discrepancy was measured by calculating the distance from the most superior aspect of the component to the femoral head. The horizontal femoral offset consisted of the perpendicular distance from the anatomical axis of the femur to the hip center of rotation, which was localized using a best-fit perfect circle. The difference between the component offset and the native femoral head offset was called *horizontal offset discrepancy* (Fig. 3).

In severe cam deformity, there is typically a small region on the anterosuperior aspect of the femoral head where there is no host bone contact with the implant after preparing the proximal femur. This area devoid of contact between the reamed femoral head and component was labeled superior gap. It was measured using the greatest width superiorly between the head and the inner surface of the superior chamfer of the prosthesis (Fig. 4). The distance between the inside of the

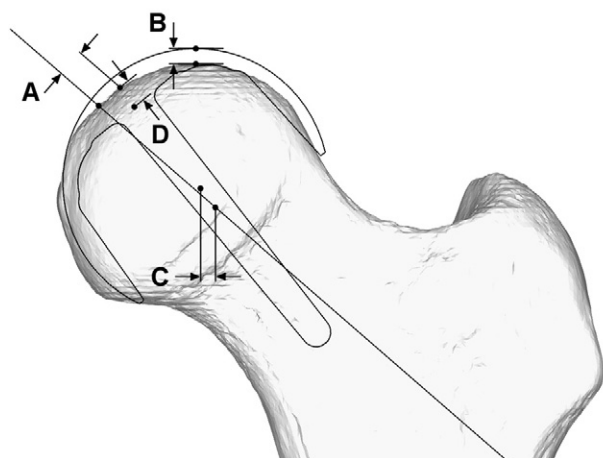


Fig. 3. Coronal plane measurements from the CT simulations. (A) Superior translation of the component measured between the neutral entry point (along the neck axis) and the actual entry point. (B) Limb length discrepancy measured between the superior aspects of the head and component. (C) Horizontal offset discrepancy measured between the centers of the head and component. (D) Reaming depth measured between actual entry point on the medial femoral head and the inner surface of the base of the component.

component and the medial femoral head along the stem axis was considered the reaming depth (Fig. 3).

The anterior femoral head-neck and component-neck offset ratios were measured from the axial CT images using the same method as for the plain radiographs. The difference between these 2 values was used to evaluate the correction of anterior offset after surface arthroplasty of abnormally shaped femoral heads. The anteroposterior translation was calculated from the neutral starting

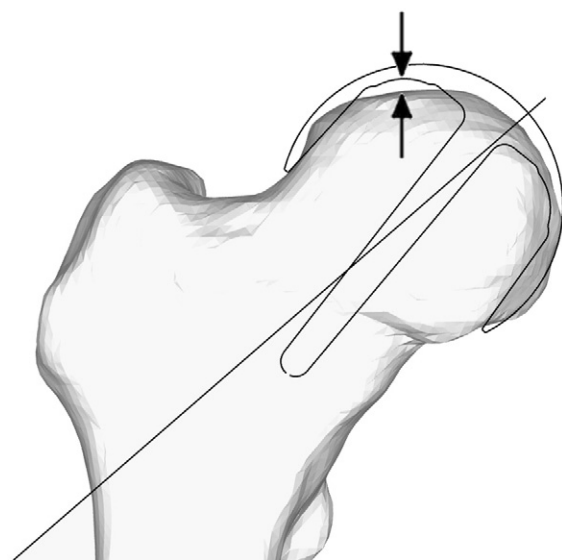


Fig. 4. Illustration depicting the superior gap between the femoral head and the inner surface of the chamfer on the prosthesis where there is no host bone contact.

point in the axial plane where the femoral neck axis crosses the tip of the head. The version of the implant was assessed by measuring the angle between the femoral neck axis and the component axis.

The frequency distribution of the modified FHR was analyzed to create 3 groups according to the severity of the deformity. The means and SDs of the radiographic and CT simulation parameters were calculated for each of these groups. Mean differences between groups were compared using Student *t* test, Fisher exact test, or analysis of variance. Results are expressed as mean \pm SD. A *P* value of less than .05 was considered statistically significant.

Results

Three categories of femoral head deformity were created using a modified FHR: normal, 0.9 or higher; mild, 0.75 to 0.9; and severe, less than 0.75 (Fig. 5). The cutoff values for each group were decided from the distribution of the FHR and using the original critical point at which a tilt deformity would be suspected [16]. A mild category was added to depict subtle deformity along the spectrum of proximal bony abnormality. There were a total of 32 normal hips (48%), 23 hips (35%) with mild deformity, and 11 hips (17%) with severe deformity of the femoral head and neck. Men were more likely to present with a severe deformity compared to women in this series ($P = .003$), accounting for 91% (10 hips) of the severely deformed hips and 96% (22 hips) with mild deformity.

The femoral neck-shaft angle measured from the AP radiographs was not significantly different within the 3 groups (normal, $131^\circ \pm 6.8^\circ$; mild, $135^\circ \pm 7.1^\circ$; severe, $136^\circ \pm 9.4^\circ$). The neck length ratio, however, was significantly smaller in the hips with mild and severe deformity when compared to normal hips (normal, 0.27 ± 0.05 ; mild, 0.24 ± 0.03 ; severe, 0.22 ± 0.03). The superior angle was also significantly flatter with progressive deformity (normal, $35^\circ \pm 7^\circ$; mild, $29^\circ \pm 7^\circ$; severe, $18^\circ \pm 8^\circ$). The inferior angle did show an increasing concavity inferiorly with worsening deformity although this was not significant (normal, $34^\circ \pm 8^\circ$; mild, $37^\circ \pm 5^\circ$; severe, $38^\circ \pm 7^\circ$). The anterior femoral offset ratio was similar between the 3 categories (normal, 0.11 ± 0.05 ; mild, 0.11 ± 0.05 ; severe, 0.11 ± 0.05) (Table 1).

All the femoral components were inserted in 10° relative valgus during the CT simulations regardless of the deformity (normal, $9.9^\circ \pm 0.2^\circ$; mild, $10^\circ \pm 0.2^\circ$; severe, $9.9^\circ \pm 0.3^\circ$). However, a severe deformity required significantly more superior translation of the entry point to allow safe insertion without notching (normal, $4.9 \text{ mm} \pm 1.4 \text{ mm}$; mild, $5.6 \text{ mm} \pm 1.4 \text{ mm}$; severe, $6.0 \text{ mm} \pm 1.6 \text{ mm}$). There was no significant difference between the groups in leg length (normal, $0.9 \text{ mm} \pm 2 \text{ mm}$; mild, $0.5 \text{ mm} \pm 2.2 \text{ mm}$; severe,

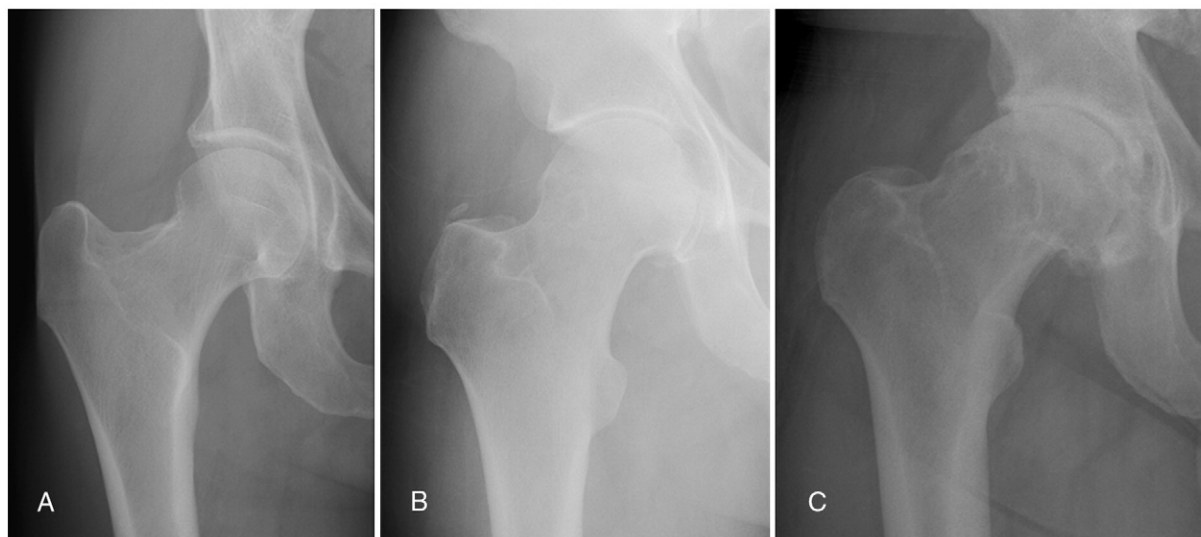


Fig. 5. Three categories of cam deformity each represented by a typical bony abnormality of the head-neck contour: A = normal (FHR = 1.04), B = mild (FHR = 0.88), and C = severe (FHR = 0.73).

−0.1 mm ± 2.3 mm), component-head size difference (normal, 3.0 mm ± 3.0 mm; mild, 2.9 mm ± 2.0 mm; severe, 1.7 mm ± 3.1 mm), or superior gap (normal, 0.5 mm ± 0.8 mm; mild, 0.4 mm ± 0.6 mm; severe, 0.8 mm ± 0.8 mm). Optimal implant positioning was also obtained by increasing the depth of reaming although this was accomplished at the expense of horizontal femoral offset. Mild and severe femoral head deformity required significantly greater reaming depth compared to normal heads (normal, 7.3 mm ± 2.5 mm; mild, 8.8 mm ± 2.7 mm; severe, 9.7 mm ± 2.6 mm). This resulted in a significant reduction of horizontal offset discrepancy after

surface arthroplasty in severe and mild deformity (normal, −2.5 mm ± 2.5 mm; mild, −4.3 mm ± 3.0 mm; severe, −4.7 mm ± 2.8 mm) (Table 1).

The anatomical parameters from the axial simulations were similar among the 3 categories of femoral head deformity. There was no difference in the preoperative anterior head-neck offset ratio (normal, 0.14 ± 0.05; mild, 0.15 ± 0.05; severe, 0.16 ± 0.05) and the postoperative component-neck offset ratio (normal, 0.19 ± 0.04; mild, 0.19 ± 0.04; severe, 0.20 ± 0.04). Each group showed an improvement in the anterior offset although the difference between the component and native femoral head

Table 1. Radiographic and CT Results Expressed as Mean and SD

	Normal (N)	Mild (M)	Severe (S)	P		
				N vs M	N vs S	M vs S
AP radiographs						
Neck-shaft angle	131 ± 7	135 ± 7	136 ± 9	.052	.062	.737
Neck length ratio	0.27 ± 0.05	0.24 ± 0.03	0.22 ± 0.03	.018	.0007	.121
Superior angle	35 ± 7	29 ± 7	18 ± 8	.004	<.0001	.0001
Inferior angle	34 ± 8	37 ± 5	38 ± 7	.131	.074	.555
Lateral radiographs						
Anterior femoral head-neck offset	0.11 ± 0.05	0.11 ± 0.05	0.11 ± 0.05	.72	.97	.817
CT simulations (coronal)						
Valgus	9.9 ± 0.2	10.0 ± 0.2	9.9 ± 0.3	.776	.74	.597
Superior translation	4.9 ± 1.4	5.6 ± 1.4	6.0 ± 1.6	.08	.027	.407
Leg length discrepancy	0.9 ± 2.0	0.5 ± 2.2	(−)0.1 ± 2.9	.456	.168	.445
Component-head size difference	3 ± 3	2.9 ± 2.0	1.7 ± 3.1	.861	.162	.227
Air bubble depth	0.5 ± 0.8	0.4 ± 0.6	0.8 ± 0.8	.747	.331	.244
Reaming depth	7.3 ± 2.5	8.8 ± 2.7	9.7 ± 2.6	.048	.012	.335
Horizontal femoral offset discrepancy	(−)2.5 ± 2.5	(−)4.3 ± 3.0	(−)4.7 ± 2.8	.02	.025	.693
CT simulations (axial)						
Anterior femoral head-neck offset	0.14 ± 0.05	0.15 ± 0.05	0.16 ± 0.05	.451	.259	.605
Anterior component-neck offset	0.19 ± 0.04	0.19 ± 0.04	0.20 ± 0.04	.923	.497	.472
Component-head offset difference	0.06 ± 0.02	0.04 ± 0.02	0.05 ± 0.02	.062	.288	.694
Posterior translation	2.2 ± 2.6	2.4 ± 3.4	2.1 ± 3.0	.763	.927	.754
Anteversión	4.5 ± 4.0	3.8 ± 4.8	3.9 ± 3.2	.554	.705	.935

A P value less than .05 is considered statistically significant.

offsets was not significant (normal, 0.06 ± 0.02 ; mild, 0.04 ± 0.02 ; severe, 0.05 ± 0.02). The implants were translated slightly posterior (normal, $2.2 \text{ mm} \pm 2.6 \text{ mm}$; mild, $2.4 \text{ mm} \pm 3.4 \text{ mm}$; severe, $2.1 \text{ mm} \pm 3.0 \text{ mm}$) along the femoral head and inserted in anteversion (normal, $4.5^\circ \pm 4.0^\circ$; mild, $3.8^\circ \pm 4.8^\circ$; severe, $3.9^\circ \pm 3.2^\circ$) to improve the alignment without any significant difference with increasing deformity.

Discussion

Malalignment of the femoral component during surface arthroplasty has been shown to increase the rate of short-term failure from periprosthetic femoral neck fractures and aseptic loosening [1,7,8,10-12]. Insertion of the implant in valgus is preferred although the exact amount of angulation remains unknown. An absolute insertion angle of 140° that has been recommended in the past [1,22] is impractical given the variability in the osseous anatomy across sex and race [23]. However, finite element analysis and biomechanical studies have suggested that 10° of relative valgus can increase the failure load and reduce the local bone strains and cement stresses associated with early femoral component failure [10,11].

Each femoral component was inserted at the desired 10° of relative valgus during the surface arthroplasty simulations. To safely insert the implant without notching, a severe deformity required more superior translation of the entry point along the lateral femoral head. Modifying the insertion technique by further translating the component superiorly, when preparing a severely deformed femoral head, is essential to achieve optimal implant alignment. Attempting to orient the component in valgus without any translation would

ultimately result in notching of the femoral neck (Fig. 6). However, excessive translation and valgus alignment both contribute to reducing the horizontal femoral offset while increasing the leg length. Studies comparing surface arthroplasty to total hip arthroplasty have shown that the femoral offset is negatively affected by a valgus orientation of the implant during resurfacing [7,22,24]. The results in the literature regarding leg length are conflicting. Most studies support an increase in leg length [1,22] although one study reported a slightly shorter limb after surface arthroplasty [24]. The simulations demonstrated that relative valgus could be achieved while preserving leg length although horizontal femoral offset was reduced as the deformity worsened.

Insertion of the femoral component in relative valgus beyond 10° may also theoretically require a larger implant to accommodate a bigger head and preserve as much reamed femoral bone as possible. The component-head size difference during the simulations was not increased with progressive deformity. This was performed by increasing the depth of reaming in severely deformed femoral heads. Altering the reaming depth also minimized the size of the superior gap allowing for a thinner cement mantle and greater host bone contact superiorly with the component. The increased reaming distance, however, further contributed to the loss of femoral offset after resurfacing of a deformed head.

The cam deformity is characterized by a varus angulation of the femoral head, a short neck length, as well as a loss of the concavity at the superior and anterior aspect of the head and neck [15-18]. The 3 categories that were created are representative of the progression of deformity that is typically expected in

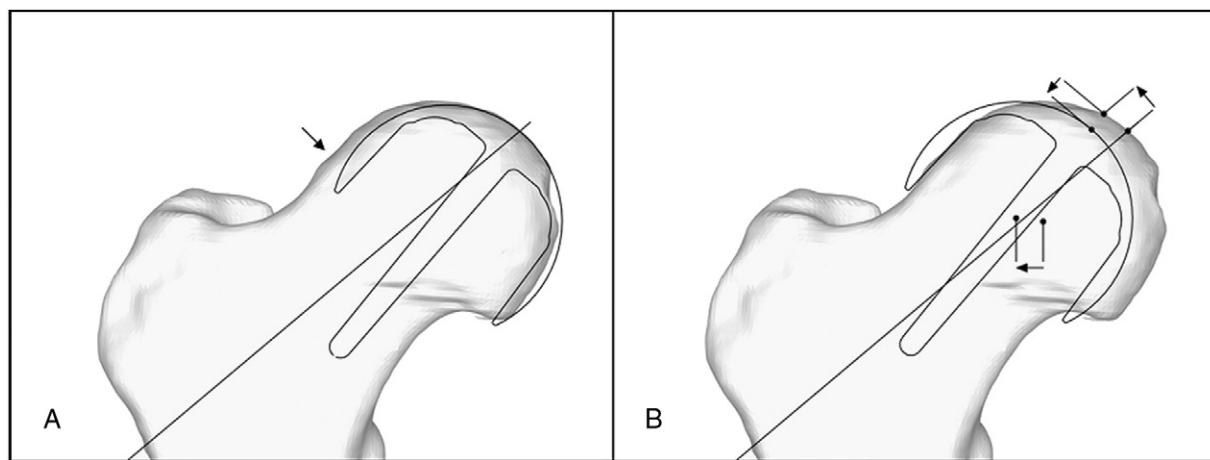


Fig. 6. Surface arthroplasty simulations illustrating the 2 possible outcomes in cam deformity when attempting to orient the femoral implant in valgus alignment with and without superior translation of the entry point. (A) Insertion of the component in valgus alignment at the neutral entry point without superior translation results in notching of the femoral neck. (B) The component can be fully seated in valgus alignment without any notching by translating the entry point superiorly and increasing the reaming depth. Limb length is unchanged although the horizontal offset is decreased.

subtle anatomical abnormalities of the proximal femur resulting in early degenerative changes from femoroacetabular impingement. Mild and severely deformed femoral heads were found to have a shorter neck length and worse superior flattening compared to normal morphology. There was no significant decrease in femoral neck-shaft angle with worsening deformity within the 3 groups. However, coxa vara does not usually occur in the cam deformity because it describes an abnormal relationship of the head and neck junction. The neck-shaft angle was measured using the femoral neck axis drawn through the middle of the neck failing to incorporate the varus tilt of the femoral head.

This study does have some limitations. Although an attempt was made to standardize the projection of the radiographs by obtaining the hip AP x-ray in 15° of internal rotation, this was highly technique dependent. Multiple radiographs of the same hip were often repeated until an adequate projection was obtained. Nevertheless, there were some slight variations despite a standardized protocol to control for such error. Patients with severe osteoarthritis occasionally have decreased range of motion and pain with internal rotation, thus, limiting the likelihood of obtaining a true AP projection. However, it has been shown that even large variations in femoral anteversion and AP radiographic projection result in only minimal error in angular measurements [23,25,26]. Kay et al [25] assessed the effect of femoral rotation on the projected femoral neck-shaft angle and found that the measured neck-shaft angle was within 5° of the actual neck-shaft angle when the femur was rotated between 50° of internal rotation and 20° of external rotation. Another limitation of this study includes the lack of validation of the femoral head deformity. Rather, we attempted to correlate the 3 categories of femoral head deformity with the classic findings that would be expected with progressive abnormality of the head-neck contour causing femoroacetabular impingement. This deformity occurs along a spectrum. The 3 categories were created using a previously described critical value that has been found to differentiate between normal and aspheric femoral heads resulting in osteoarthritis [16].

Preoperative measurements of femoral neck-shaft angle in hip resurfacing have shown poor interobserver reliability compared to postoperative stem-shaft angle [26]. There is much inconsistency in the literature on how to measure the femoral neck axis and the native neck-shaft angle. The femoral axis is typically obtained by drawing a line connecting the center of the femoral head to the midpoint of the femoral neck isthmus [25-27]. However, using the center of the femoral head to measure the neck axis is inappropriate given that this point will change according to the severity of the deformity. The original definition of the femoral neck axis by Murray [16] depicted a line drawn through the

middle of the neck joining 2 center points “between (1) the most lateral part of the greater trochanter and the most medial part of the lesser trochanter and (2) of the narrowest portion of the femoral neck.” This description of the femoral neck axis was slightly modified in our study. The lateral reference point was the same along the intertrochanteric line although the medial midpoint was located between the superior and inferior junction of the head and neck rather than at the narrowest portion of the femoral neck. This reference point was chosen to limit the number of variables because the same point was used to determine the femoral neck length, the superior and inferior angle, as well as center of rotation to align the femoral component in valgus. We found this point to be reproducible as it is not affected by the severity of deformity, which occurs medial to the head and neck junction [15,16,18,19,28,29]. Always choosing the same point can minimize the potential for further errors when performing multiple measurements from plain radiographs.

The 3 categories of femoral head deformity are simple and easily measured using a standard AP radiograph of the hip. The anterolateral location of the deformity has led some to believe that it is better observed on a lateral view [15,17]. A study evaluating 6 different radiographic projections of the hip found that the Dunn view (in 45° hip flexion, neutral rotation, and 20° abduction) was the most sensitive for detecting femoral head asphericity [28]. The anterior offset α angle was used to calculate the severity of deformity from each projection although it was originally described using a best-fit concentric circle from magnetic resonance axial images parallel to the femoral neck axis and passing through the center of the head [30]. The α angle was not designed to assess the superior deformity of the femoral head and cannot be applied to AP radiographs because these have shown poor reproducibility when assessing for femoroacetabular impingement [31].

Other methods have been developed to measure the abnormal relationship between the head and neck. The anterior femoral head-neck offset ratio uses a cross-table lateral radiograph that is occasionally difficult to standardize between patients [14]. The comparison group in a recent study consisted of patients with nonarthritic hip pain from femoroacetabular impingement that either had a spherical head with a round appearance or an abnormal shape from a pistol grip deformity [21]. Those with an aspherical head had a larger α angle although the anterior femoral head-neck offset ratio was similar compared to normal shaped heads. We were also unable to show a difference in the femoral offset ratio with progressive deformity of the femoral head using either radiographic or CT images. This suggests that structural abnormalities of the head-neck contour may not always be present on a lateral x-ray or that the femoral offset ratio is unreliable in

detecting subtle anatomical variations because of technical difficulties in obtaining a true lateral projection. Standard radiographic evaluation often underestimates the cam deformity because the abnormality is mostly located in the anterosuperior region of the femoral head and neck [32]. Magnetic resonance is usually the preferred modality to image structural deformity of the femoral head although it is not practical to routinely assess every patient with advanced osteoarthritis awaiting hip resurfacing [33].

Surface arthroplasty simulations were performed to better understand how progressive deformity influences the positioning of the femoral component during resurfacing. Severe flattening and segmental bone loss require adjustments in the surgical technique to safely insert the implant in optimal alignment. The cam deformity is 3-dimensional and best visualized using 2 orthogonal radiographs including an AP and lateral view. We measured the severity of the deformity using only an AP radiograph of the hip given that it is more critical in resurfacing to obtain valgus alignment in the coronal plane to avoid early failure from femoral neck fracture and aseptic loosening. Optimal implant orientation was accomplished by translating the entry point superiorly and increasing the reaming depth during preparation of deformed femoral heads. The amount of superior translation and reaming depth required to insert the component in valgus can be determined by measuring the severity of the deformity preoperatively. Computed tomographic navigation can be used at the time of surgery to more accurately insert the femoral implant in all planes [34]. Optimal alignment was also achieved while preserving the leg length, minimizing the component size, and maximizing the amount of host bone contact, although the horizontal femoral offset was reduced. The clinical implication of a loss in horizontal offset after hip resurfacing is unclear. It appears as though relative valgus is preferable to maintaining femoral offset because larger size heads seem to limit the risk of dislocation after resurfacing. These findings suggest that the femoral component can be safely inserted with optimal positioning during surface arthroplasty by modifying the surgical technique in the face of progressive deformity of the femoral head and neck.

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