Influence of cementless femoral stems inserted in varus on functional outcome in primary total hip arthroplasty

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Introduction: Historically, cemented total hip arthroplasty (THA) femoral stems inserted in varus have yielded poor clinical results. Few studies to date have addressed the question of the effects of varus alignment on cementless stems. We conducted a retrospective review of 125 uncemented THA femoral stems implanted by a single surgeon from 1994 to 1999. **Methods:** We conducted a retrospective radiographic review of 125 cementless primary THA femoral stems implanted by a single surgeon who used the Watson-Jones approach; we identified 16 stems implanted in varus, defined as $\geq 5°$ and thus analyzed the effect of varus alignment on functional outcome. We matched varus stems to a cohort of 16 nonvarus cementless stems and measured radiographic signs of loosening and subsidence, defined as > 2 mm. **Results:** At 4 years postsurgery, there was no significant difference in range of motion or in Harris Hip Score ($p > 0.5$), and no cases showed evidence of radiographic loosening or subsidence ($p = 0.226$). **Conclusions:** Study results suggest there is no consequence of varus femoral alignment in the cementless stems. Although it is not recommended to implant stems in varus, there were no apparent radiographic or clinical consequences observed at up to 4 years postoperative in this small case series.

Introduction : Les tiges fémorales cimentées utilisées en arthroplastie totale de la hanche (ATH) insérées en varus ont toujours produit des résultats cliniques médiocres. Peu d'études ont porté jusqu'à maintenant sur les effets de l'alignement en varus sur les tiges non cimentées. Nous avons procédé à une étude rétrospective de 125 tiges fémorales primaires non cimentées utilisées en ATM et implantées par le même chirurgien entre 1994 et 1999. **Méthodes :** Nous avons procédé à un examen radiographique rétrospectif de 125 tiges fémorales ATH primaires non cimentées implantées par le même chirurgien qui a utilisé la méthode Watson-Jones. Nous avons trouvé 16 tiges implantées en varus, défini comme $\geq 5°$ et ainsi analysé l'effet de l'alignement en varus sur le résultat fonctionnel. Nous avons comparé les tiges en varus à une cohorte de 16 tiges non cimentées et non en varus, et mesuré les signes radiographiques de desserrage et d'affaissement, établis à > 2 mm. **Résultats :** Quatre ans après l'intervention chirurgicale, il n'y avait pas de différences importantes dans l'amplitude du mouvement ou le score de Harris pour la hanche ($p > 0,5$) et aucun cas ne montrait de signe de desserrage ou d'affaissement à la radiographie ($p = 0,226$). **Conclusions :** Les résultats de l'étude indiquent que l'alignement du fémur en varus n'a pas de conséquence sur les tiges non cimentées. Même s'il n'est pas recommandé d'implanter des tiges en varus, on n'a pas observé de conséquences radiographiques ou cliniques apparentes jusqu'à quatre ans après l'intervention dans cette série limitée de cas.

Poor functional outcome and survivorship of cemented stems implanted in varus have been well documented. Premature failure in this setting has been attributed to femoral varus alignment creating unfavourable proximal stresses in the cement mantle, which has been thinned in zones 3 and 7 by the varus placement of the stem, with consequent predilection for failure.[1–9] In a long-term retrospective review of the cemented Charnley total hip at 16–25 years postoperative, Devitt and colleagues[1] determined a 75% survival rate of the implant at 20 years postoperative. For the stems placed in varus, the authors cite a

35.7% revision rate. They also found that radiographic loosening of the acetabular component was well tolerated, but loosening of the femoral component was significantly associated with pain.

Despite the poor results of cemented varus stems, few studies to date have addressed the question of the effects of varus alignment on cementless stems. The fundamental reason for this is self-evident in that, given their experience with cemented stems, surgeons will make every effort to avoid placing the stem in varus. The purpose of this study is to evaluate stems implanted in varus relative to the long axis of the femur. The functional and radiographic outcomes of these stems were reviewed and compared with a matched control group of cementless stems implanted in neutral alignment.

Methods

We conducted a retrospective radiographic review of a cohort of 125 cementless primary total hip arthroplasties (THAs) to identify femoral stems implanted in varus. The proximally coated nontapered stem (OmnifitHA/Porous, Stryker Howmedica Osteonics, Rutherford, NJ) THAs were implanted by a single surgeon from 1994 to 1999. The surgeon used the Watson-Jones approach. This approach, by virtue of its preservation of the abductor mechanism, has the potential to compromise femoral exposure and stem implantation. Within this single-surgeon group, we identified 16 stems implanted in varus relative to the long axis of the femur. The surgical technique involved reaming and broaching. In line with Khalily and colleagues,[10] we defined varus alignment as femoral stem alignment ≥ 5° on radiographic assessment. The angle formed between the medial endosteal cortex of the femoral shaft and the shaft of the implant was used to determine the degree of varus angulation (Fig. 1). All analyses were conducted with anteroposterior (AP)

radiographs of the affected hip. Of the study cohort, 16 of 125 (12.8%) femoral stems were confirmed in varus. These 16 varus stems (11 porous coated, 5 hydroxyapatite coated) were matched 1:1 for preoperative diagnosis, age, sex and implant type to a cohort of 16 nonvarus uncemented stems implanted by the same surgeon over the same study period.

All patients underwent radiographic and functional assessment conducted by a clinical research nurse at routine assessment intervals, including 1 week preoperative and 6 weeks (standard deviation [SD] 1 wk), 6 months (SD 2 wk), 1 year (SD 4 wk), 2 years (SD 4 wk) and 4 years (SD 4 wk) postoperative. Functional outcome included Harris Hip Score,[11] pain and presence of limp as measured by the Harris Hip Score and global hip range of motion. The Harris Hip Score rates pain on a scale ranging from 10 to 44 points, with a score of 10 indicating marked pain with serious limitations, 20 indicating moderate pain, 30 indicating moderate occasional pain, 40 indicating slight pain and 44 indicating no pain. Limp is rated on a scale ranging from 0 to 11 points, with a score of 0 indicating severe limp/inability to walk, 5 indicating moderate limp, 8 indicating slight limp and 11 indicating no limp.

All primary THA patients underwent the same standard postoperative physiotherapy protocol including exercises, mobility and gait training commencing 1 day after surgery. Standard discharge criteria was based on independent patient transfer, ability to climb stairs as appropriate, walking safely with a walker, ability to manage exercise protocol independently, and demonstrated knowledge and safety in hip precautions (i.e., flexion, adduction, limited rotation).

At our institution, a standardized anteroposterior radiograph of the hip was taken with the hip in neutral rotation. Radiographic signs of loosening and subsidence were measured. According to the method described

by Engh and colleagues,[12] loosening was defined as the presence of radiosclerotic lines in femoral zones 1–7, where stems with a reactive line < 50% of porous coated area are stable and stems with a reactive line > 50% are deemed unstable. Subsidence was defined as > 2 mm, according to Engh and others.[12] Radiographic analysis of subsidence was calculated as the difference in 4-year and 6-week postoperative distance of the greater trochanter tip to the neck angle (using head diameter measurements to correct for variation in radiographic magnification/technique). All radiographic analyses were conducted by 3 independent assessors using the Imagika (Clinical Measurements Corporation, NJ) radiographic image enhancement system. This is a useful computerized tool for facilitating radiographic measurement; however, the measurements obtained retain an element of measurement error and are not comparable with RSA in terms of accuracy and precision. In addition, all hips were

FIG. 1. Postoperative anteroposterior radiograph of cementless stem implanted in ≥ 5° of varus. Varus alignment measurement technique, in line with Kahlily and others.[10] Arrow indicates angle in degrees. Distal lateral endosteal reaming is also evident at the tip of the stem.

retemplated with company-supplied femoral templates (Stryker Howmedica Osteonics, Rutherford, NJ) to address the issue of potential undersizing of the varus stem.

Paired *t* tests were conducted on all continuous outcome variables; the chi-square test and Fisher's exact test were used on categorical variables. A value of *p* < 0.05 was considered statistically significant.

Results

The matched cohorts comprised 10 men with mean age 66 (standard deviation [SD] 6.4) years and 5 women with mean age 62 (SD 17) years. Fifteen of 16 patients in each group underwent primary THA for osteoarthritis and 1 of 16 for avascular necrosis (Table 1). Of the study cohort, 109 (87.2%) hips were in neutral alignment, compared with 16 (12.8%) varus hips. Given the limitations of the radiographic measurements, mean stem angulations of 6.22° (SD 0.88°) and 0.39° (SD

1.96°) (*p* < 0.005) were calculated for varus and nonvarus groups at 4 years postoperative, respectively. All varus stems were initially placed in varus. Given the limitations of the radiographic measurements, we were unable to identify any progression of the varus angle of the stem suggestive of adaptive remodelling of the femur.

We could not show any statistically significant difference in Harris Hip Score, hip range of motion, pain or limp scores between the varus and nonvarus hips at any of the assessment intervals, including 1 week preoperative and 6 weeks, 6 months, 1 year, 2 years and 4 years postoperative (*p* > 0.05). At 4 years postoperative, the mean Harris Hip Score was 88.3 (SD 11.4) in the varus group and 91.5 (SD 9.2) in the nonvarus group (*p* = 0.599). Mean global hip range of motion was 219.4 (SD 24.7) for the varus group and 228.8 (SD 27.8) for the nonvarus group (Table 2).

At 4 years postoperative, we did

not find any significant difference in pain scores among any of the rated pain scale attributes between the varus and nonvarus groups: no pain *p* = 0.723, slight pain *p* = 0.719 and moderate occasional pain *p* = 0.484. Likewise, we could not find any significant difference in limp scores at 4 years postoperative, with 12 of 16 patients in each group indicating the absence of a limp at this follow-up interval (*p* > 0.05).

After retemplating, 2 of the nonvarus stems were felt to be potentially undersized by an order of 1 stem size, whereas all 16 of the varus stems were undersized by an average of 1.6 (SD 0.63) sizes. Additionally, only one of the nonvarus stems showed a slight trace of distal lateral endosteal reaming on the initial postoperative film, whereas 12 of 16 varus stems showed unequivocal (varying grades) distal lateral endosteal reaming (Fig. 1). Of the 4 varus stems that did not show evidence of distal lateral endosteal reaming, all were undersized by at least 2 sizes on retemplating. One calcar crack fracture in each group was treated by cerclage wiring, with no clinical or radiographic consequences being noted. No distal fractures were encountered in either group.

No cases showed evidence of radiographic loosening at 4 years postoperative, and no radiosclerotic lines were apparent in either group. Given the limitations of the radiographic measurement technique available to us, we could not identify any difference in subsidence between the varus and the nonvarus hips. At 4 years postoperative, none of the varus stems had gone on to subsequent revision THA.

Discussion

Numerous studies in the literature support the poor outcomes seen in cemented femoral stems implanted in varus.[1-9] Ebramzadeh and colleagues[4] used survival analysis over a 21-year period to assess the long-

Table 1

Demographics and preoperative scores

Characteristics	Varus hips (*n* = 16)	Nonvarus hips (*n* = 16)	*p*
Age, yr	65.1 (10.5)	65.6 (7)	0.881
BMI	29.3 (5)	30.3 (5.5)	0.729
Men:women	11:5	11:5	—
Diagnosis, no.			
Osteoarthritis	15	15	—
AVN	1	1	—
Global hip range of motion	141.8 (15.2)	153.1 (58)	0.557
Harris Hip Score	43 (15.4)	41.3 (12.5)	0.819
Pain rating, no.			
No pain	0	0	1.000
Slight pain	0	0	1.000
Moderate occasional	1	1	1.000
Moderate	3	7	0.127
Marked pain	12	8	0.144
Limp, no.			
None	0	1	1.000
Slight	1	2	1.000
Moderate	10	8	0.476
Severe	5	3	0.685

AVN = avascular necrosis; BMI = body mass index.
*Unless otherwise indicated.

term outcome in 836 cemented femoral components. Progressive loosening, fracture of the cement and radiolucent lines at the stem–cement or bone–cement interfaces were more likely to develop in stems that were oriented in ≥ 5° of varus. The noted correlations were true regardless of the implant material (titanium and stainless steel). Jaffe and others[2] found a similar result when they examined 215 cemented femoral stems. Of the stems implanted in varus, 37.5% went on to failure and subsequent revision. It is hypothesized that the increased rate of failure of cemented stems oriented in varus is a result of a combination of significantly decreased posteromedial calcar cement mantle and abnormal forces through the calcar and at the distal lateral tip of the prosthesis.[4] For the most part, orientation is under surgeon control and is avoidable.

Cementless femoral stem fixation has become a widely accepted procedure with favourable clinical outcomes. Very few studies have shown poor clinical results,[13–17] with most studies reporting a high degree of good to excellent results with 4–9 years follow-up.[18–25] Laupacis and others[24] recently reported a significantly higher revision rate for both cemented acetabular and cemented femoral components at an average of 6.3 years follow-up. The study compared 124 patients with cemented stems to 126 patients with cementless stems. Of the femoral revisions, 12 were cemented and 1 was cementless. The authors did not report whether the revisions were implanted in varus or neutral. This is one of the only known studies to compare femoral stem fixation in a prospetive, randomized controlled trial.

When examining the literature on cementless stems, the consequences of varus orientation seem to be less important. These findings are based on the few studies that have compared varus and normally aligned femoral prostheses. Pernell and colleagues[26] studied strain distribution and subsidence in a canine model and found that stems implanted in varus have an improved fit along the proximal-medial and distal-lateral cortices, resulting in an increase in tensile hoop strains. Varus alignment thus showed similar failure properties and a nonsignificant difference in subsidence than properly aligned and sized stems. Schneider and others[22] reported on 3732 cementless femoral stems. No significant correlations were found between varus stem alignment and function, survival, migration or radiolucent lines. In this series of patients, varus alignment of the prosthesis did not have any adverse effects on radiographic[12] or clinical outcomes, as measured by the Harris Hip Score. These results are directly comparable with those published by Khalily and others.[10] In a radiographic review of 585 cementless femoral components with a minimum 5-year follow-up, Khalily and colleagues identified 23 stems implanted in varus (4%) with no significant difference in radiographic (radiolucent lines) or clinical outcome as measured by the Harris Hip Score. None of the 585 cases required revision at 5 years postoperative. These data support the findings in our current study. Similarly, we could not show any statistically significant difference between the varus and non-varus group among any of our outcome measures, including range of motion, Harris Hip Score

Table 2

Clinical outcomes at 6 weeks and 4 years postoperative

Clinical outcomes	Hip group; mean (and standard deviation)*		p
	Varus hips (n = 16)	Nonvarus hips (n = 16)	
Global hip range of motion			
6 weeks	177.9 (24.8)	177.7 (37.4)	0.988
4 years	219.4 (24.7)	228.8 (27.8)	0.563
Harris Hip Score			
6 weeks	67.3 (10.6)	63.1 (11.9)	0.508
4 years	88.3 (11.4)	91.5 (9.2)	0.599
Pain rating at 6 weeks, no.			
No pain	10	9	0.719
Slight pain	4	1	0.333
Moderate occasional	2	5	0.394
Moderate	0	1	1.000
Marked pain	0	0	1.000
Pain rating at 4 years, no.			
No pain	9	8	0.723
Slight pain	7	6	0.719
Moderate occasional	0	2	0.484
Moderate	0	0	1.000
Marked pain	0	0	1.000
Limp at 6 weeks, no.			
None	0	1	1.000
Slight	2	1	1.000
Moderate	11	11	1.000
Severe	3	3	1.000
Limp at 4 years, no.			
None	12	12	1.000
Slight	4	3	1.000
Moderate	0	1	1.000
Severe	0	0	1.000

*Unless otherwise indicated.

and pain and limp as measured by the Harris Hip Score.

Despite the lack of adverse consequence demonstrated in the current study with varus stem placement, the results should be considered with caution. In fact, no author at our institution currently uses the Watson-Jones approach, partly because of the difficulty in achieving neutral stem placement, particularly in muscular individuals. Although we did not identify any difference in subsidence between the varus and the nonvarus hips, given the limitations of the radiographic measurement technique available to us, the measurements retain an element of measurement error and are not comparable with RSA in terms of accuracy and precision. Owing to the very small sample size in the current study, the power is limited. Having said this, the incidence of varus stem implantation is low, making it unlikely to yield a sample size of adequate power, nor do we feel it would be desirable to have a large series to report. This unique cohort of one surgeon's experience at least allowed us to determine whether there were any detrimental effects of varus stem placement; none could be identified in the short-term with this particular stem.

Although it is not recommended to implant cementless stems in varus, the study results suggest that radiographic and clinical problems associated with implanting cementless femoral stems in varus appear to be nonconsequential in the short-term. Compared with the literature, varus stem placement may be better tolerated without cement. This study only reports 4-year follow-up data for all cases, thus patients will need to be followed for a longer duration to further examine the effect of varus implantation of cementless femoral stems. There is potential for the stresses associated with these varus stems to induce bone remodelling in the proximal femur, which may be prejudicial to the long-term survivorship of the implant.

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