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Original article

Comparative study of stem anteversion using a cementless tapered wedge stem in dysplastic hips between the posterolateral and anterolateral approaches

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ABSTRACT

Background: In total hip arthroplasty (THA), the concept of combined anteversion is accepted as one of best indicators of prosthetic joint stability. Technical parameters may influence the stem and cup anteversion. We therefore investigated if stem anteversion could be influenced by surgical approaches in cementless THA using a tapered wedge stem with stem-first technique.
Hypothesis: We postulated that the type of approach, posterolateral (PLA) or anterolateral approach (ALA), would influence stem anteversion in dysplastic hip patients. We asked (1) whether stem anteversion was higher in the PLA group and (2) how postoperative stem anteversion was correlated to preoperative femoral anteversion in each group.
Patients and Methods: We retrospectively compared two groups of hips that underwent THA using a tapered wedge stem with the posterolateral (PLA group; 154 hips) or anterolateral (ALA group; 81 hips) approaches. Computed tomography was utilized to measure femoral neck and stem anteversion. To investigate related factors that affect stem anteversion, a stepwise regression analysis was performed.
Results: The stem anteversion in the PLA and ALA groups was 43.7° ± 9.8° and 34.0° ± 12.3°, respectively ($p < 0.01$). The stepwise selection process resulted in a model involving femoral neck anteversion and surgical approach ($p < 0.01$). The stem anteversion of the ALA group ($r = 0.75$, $p < 0.01$) was better correlated to femoral neck anteversion than that of the PLA group ($r = 0.52$, $p < 0.01$).
Discussion: The stem implantation through the ALA is thought to be more restricted than that through the PLA due to the difference of difficulty in femoral exposure. Tapered wedge stems, which are relatively thin and flat, have a high degree of freedom in the femoral canal. Consequently, in cementless THA using a tapered wedge stem, the surgical approaches affected stem anteversion differently. Stem anteversion was more anatomically restored to femoral neck anteversion through the ALA than through the PLA.
Level of evidence: III, retrospective case-control study.

1. Introduction

In total hip arthroplasty (THA), the concept of combined anteversion (CA) of the stem and cup is accepted as one of best indicators of hip prosthetic joint stability [1,2]. Intraoperatively, some surgeons estimate the stem anteversion and then adjust the cup anteversion to adapt the CA of the stem and cup to the safe zone [1,3]. This technique is useful to avoid prosthetic impingement; the appropriate CA has been reported to range from 30° to 60° [1,4,5]. In cementless THA, the anteversion of a tightly press-fit femoral stem is restricted by the anatomy of the femoral neck, diaphyseal bow, and anteroposterior isthmus at the level of the lesser trochanter created by the calcar femorale [6]. Previous studies have reported that the stem anteversion is larger than the femoral anteversion [3,7–9]. In Japan, more than 90% of hip osteoarthritis cases are

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caused by acetabular dysplasia [10,11]. Because the femoral neck anteversion of dysplastic hips is larger in average and more various than that of normal hips [12], it might be difficult to achieve the appropriate CA in patients with hip dysplasia. Therefore, even if joint stability can be achieved in dysplastic hips with various femoral neck anteversion using the stem-first technique under the concept of CA [3], caution must be taken to avoid unexpected stem anteversion, which may influence postoperative joint stability.

Technical parameters, in particular the type of approach, may influence the final stem anteversion. In fact, numerous publications already showed that it could influence cup anteversion [13–17]. There is no comparative study of stem anteversion between different approaches in cementless THA using tapered wedge stem. Therefore, we postulated that the type of approach, anterolateral or posterolateral, would influence stem anteversion in cementless THA for dysplastic hip. We asked (1) whether stem anteversion was higher in the posterolateral approach (PLA) group than in the anterolateral approach (ALA) group and (2) how postoperative stem anteversion was correlated to preoperative femoral neck anteversion in each group.

2. Patients and Methods

2.1. Patients

This retrospective study was approved by the institutional research ethics committee, and informed consent from the patients was not required because of the study's retrospective nature. A total of 434 primary cementless THAs using the tapered wedge stem (Accolade TMZF 127; Stryker Orthopaedics, Mahwah, NJ) were performed in our hospital between October 2009 and December 2013. Because we have used a modular-type stem for patients with femoral neck anteversion of > 60° and < −15°, this study did not include such patients. Among the 434 THAs, 341 THAs were performed for patients with secondary osteoarthritis due to hip dysplasia. We excluded 95 THAs in the supine position to eliminate the influence of the operative position, and only extracted data of 246 THAs that were performed in the lateral decubitus position to compare the posterolateral and anterolateral approaches. Eleven THAs for patients with hip flexion contracture of 30° or higher were also excluded. Finally, the 235 remaining THAs were categorized into the following groups according to the approach used: PLA group with 154 THAs using the posterolateral approach; and ALA group with 81 THAs using the anterolateral approach (Fig. 1).

The patient characteristics (age, sex, body mass index, range of motion [flexion and abduction], and disease) and radiographic data (leg length discrepancy [LLD], canal flare index, and femoral neck anteversion) were compared between the PLA and ALA groups.

2.2. Methods of surgery

Patients with restricted ROM < 60° flexion or those requiring more than 2-cm leg lengthening were selected for PLA. All surgeries were performed by senior authors (TJ, NT, DK). Before determining the cup anteversion on the basis of the combined anteversion concept [1,18], we first prepared the femur, taking into account the stem anteversion [19]. We implanted stems using a straight femoral broach for the posterolateral approach and using an offset femoral broach for the minimally invasive anterolateral approach [20]. As patients with femoral neck anteversion of > 60° and of < −15° were excluded in this study, rasping was performed without any intention of controlling stem anteversion to ensure that the press-fit insertion would have maximum stability, and the maximum stem size was inserted to the femoral medullary canal.

2.3. Methods of assessment

All patients underwent computed tomography (CT) examinations preoperatively and at 3 months postoperatively. The patients with their hip and knee fully extended were placed in a supine position on the examination table. Scanning was performed from the pelvis to the knees. We confirmed that there was no hip or knee contracture on the anterior and lateral scout view images. Femoral neck anteversion was measured based on a method reported by Taniguchi et al. [9]. Stem anteversion was the angle formed by the stem neck major axis and the femoral posterior condylar line. Measurements were conducted twice with at least 1 month between measurements by 2 orthopedic surgeons (NT and SO). Spearman's correlation analysis showed intraobserver reliabilities; 0.93 for femoral neck anteversion ($p < 0.01$) and 0.97 for stem anteversion

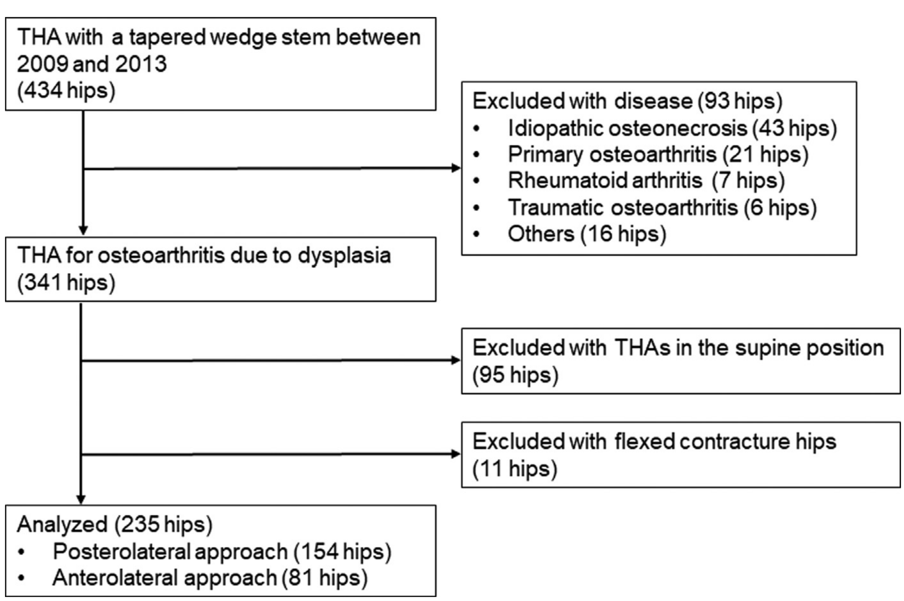

Fig. 1. Flowchart showing the selection of the patients. A total of 434 primary cementless total hip arthroplasties (THAs) using the tapered wedge stem were performed. We extracted data of 341 THAs performed for patients with secondary osteoarthritis due to hip dysplasia. We excluded 95 THAs in the supine position and 11 THAs for patients with hip flexion contracture of 30° or higher. Finally, 235 THAs were included in the current study.

($p < 0.01$) and interobserver reliabilities; 0.89 for femoral neck anteversion ($p < 0.01$) and 0.95 for stem anteversion ($p < 0.01$).

The cup inclination was defined as the angle between the interteardrop line and the line connecting the most superior and inferior aspects of the cup. The radiographic cup anteversion was measured and calculated on the basis of the CT data [21]. The CA was calculated using Widmer's formula (CA = cup anteversion + 0.7 stem anteversion) [18].

The items investigated in the current study were as follows: (1) the comparison of the stem and cup anteversion, CA, and the anteversion increase (postoperative stem anteversion (°) minus preoperative femoral anteversion (°)) between PLA and ALA, and (2) the determination of the related factors that influence the stem anteversion and the measurement of the correlation between the femoral neck and stem anteversions in each group.

2.4. Statistical analysis

We used Welch's *t*-test to compare the background characteristics, radiographic data, and surgical data in the PLA and ALA groups and the *F*-test to compare the variability of the anteversion increase around the mean. We also assessed the influence of the patient characteristics (age, sex, body mass index, range of motion [flexion and abduction], and disease), radiographic data (LLD, canal flare index, and femoral neck anteversion), stem size, and surgical approach on the stem anteversion angle using a stepwise regression analysis for the multivariate analysis. We calculated the Pearson correlation coefficients between the stem and femoral anteversions in each group. Statistical analyses were performed using IBM SPSS Statistics (version 24; IBM SPSS Inc, Chicago, IL). Significance level was set at $p < 0.05$. All the radiological and statistical analyses were performed by a co-author (SO) who was not involved in the surgeries.

A post hoc sample size calculation (G*Power 3; Düsseldorf University, Düsseldorf, Germany) [22] was performed to assure that there was adequate statistical power to assess significant differences of anteversion increases between the groups compared. A post hoc power analysis using effect size d = 0.86 and $\alpha = 0.05$ showed that the statistical power was 0.95 in anteversion increase.

3. Results

The two groups were comparable in terms of patient characteristics and radiographic data, except for the preoperative flexion and LLD (Table 1).

The stem anteversion in the PLA and ALA groups was 43.7° ± 9.8° and 34.0° ± 12.3°, respectively ($p < 0.01$). The anteversion increase in the PLA and ALA groups was 21.4° ± 11.8° and 12.3° ± 9.2°, respectively ($p < 0.01$). The stem anteversion and anteversion increase in the PLA group were significantly greater than those in the ALA group. The cup anteversion was larger in the ALA group than in the PLA group (PLA group: 18.2° ± 7.5°, ALA group: 22.2° ± 7.2°, $p < 0.01$). The cup inclination in the ALA group was steeper than that in the PLA group (PLA group: 39.4° ± 6.2°, ALA group: 43.5° ± 6.4°, $p < 0.01$). The CA was 49.0° ± 9.7° in the PLA group and 46.0° ± 10.4° in the ALA group ($p = 0.03$) (Table 2).

In the multivariate analysis using stepwise regression analysis, the femoral neck anteversion and the surgical approach had a significant correlation with the stem anteversion (standard regression coefficient: 0.579 and −0.401, respectively, $p < 0.01$) (Table 3). There was a positive correlation ($r = 0.52$; $p < 0.01$) between the stem and femoral neck anteversions in the PLA group, whereas a strongly positive correlation ($r = 0.75$; $p < 0.01$) was found in the ALA group (Fig. 2).

Table 1
Patient characteristics and radiographic data.

	Posterolateral approach group	Anterolateral approach group	*p* value
Number of hips	154	81	
Age[c] (y)	65.8 ± 10.5 (39–87)	67.3 ± 9.9 (38–89)	0.38[a]
Sex (Female/Male)	130/24	68/13	1.00[b]
Body mass index[c] (Kg/m^2)	23.5 ± 4.1 (15.3–38.2)	23.5 ± 3.1 (17.6–32.6)	1.00[a]
Preoperative ROM of hip joint (°)			
Flexion[c]	72.2 ± 19.4 (15–120)	91.3 ± 16.3 (60–130)	< 0.01[a]
Abduction[c]	14.8 ± 10.1 (−10–35)	16.0 ± 8.8 (−5–35)	0.37[a]
Leg length discrepancy (mm)	10.1 ± 11.1 (−1.0–39.9)	7.4 ± 10.1 (−4.7–19.2)	0.02[a]
Disease	Dysplastic osteoarthritis (100%)	Dysplastic osteoarthritis (100%)	
Canal flare index[c]	4.1 ± 1.0 (1.5–7.8)	3.9 ± 0.7 (2.4–5.9)	0.10[a]
Femoral neck anteversion[c] (°)	22.0 ± 13.7 (−12.5–59.8)	21.6 ± 13.4 (−8.4–57)	0.83[a]

[a] Mann–Whitney U test.
[b] Fisher's exact test.
[c] Values are given as mean ± SD (range).

Table 2
Surgical data.

	Posterolateral approach group	Anterolateral approach group	*p* value
Stem size[c]	2.7 ± 0.9 (0–7)	2.7 ± 1.2 (0–6)	0.70[a]
Stem neck-shaft angle (°)	127	127	–
Stem anteversion[c] (°)	43.7 ± 9.8 (18.8–72.8)	34.0 ± 12.3 (2.1–65.3)	< 0.01[a]
Anteversion increase[c] (°)	21.4 ± 11.8 (−6.4–50.7)	12.3 ± 9.2 (−14.7–39)	< 0.01[a]
Variability			< 0.01[b]
Cup anteversion[c] (°)	18.2 ± 7.5 (0.7–38.3)	22.2 ± 7.2 (3.3–43.6)	< 0.01[a]
Cup inclination[c] (°)	39.4 ± 6.2 (22.7–55.5)	43.5 ± 6.4 (27.7–58.6)	< 0.01[a]
Combined anteversion[c] (°)	49.0 ± 9.7 (24.4–73.1)	46.0 ± 10.4 (14.5–75.0)	0.03[a]

[a] Mann–Whitney U test.
[b] F test.
[c] Values are given as mean ± SD (range).

Table 3
Factors related to stem anteversion.

	Standard regression coefficient	*p*-value
Age	−0.092	0.053
Sex	0.001	0.979
Body mass index	0.023	0.628
Preoperative ROM (flexion)	0.003	0.955
Preoperative ROM (abduction)	0.064	0.178
Leg length discrepancy	−0.055	0.249
Canal flare index	0.043	0.372
Femoral neck anteversion	0.579	< 0.001
Surgical approach (PLA: 0/ALA: 1)	−0.401	< 0.001
Stem size	−0.001	0.988

ROM: range of motion; PLA: posterolateral approach; ALA: anterolateral approach.

4. Discussion

The stem anteversion and anteversion increase in the PLA group was greater than those in the ALA group. We assume that this result is related to the stem sagittal alignment. Previous comparative studies of stem position between different surgical approaches reported that approaches affected stem sagittal alignment [8,13,14]. The frequency of flexed implantation in the sagittal plane was higher in the anterior approaches than in the posterior approach [8]. Stem sagittal alignment can affect anteversion increase (Fig. 3). Hirata et al. [7] reported that as the stem sagittal alignment was tilted posteriorly by 1°, the anteversion increased by 2.3° using a metaphyseal filling stem through PLA. Depending on surgical approaches, there are differences in the difficulty of exposing stem insertion point of proximal femur and in the sagittal alignment of the stem. Thus, surgical approaches affect stem anteversion and anteversion increase.

The current study has several limitations. First, it was not a prospective randomized study. However, there was no significant difference between the PLA and ALA groups in terms of patient characteristics and radiographic data, except for the preoperative hip flexion angle and LLD. The difference in the preoperative hip flexion angle and LLD did not affect the stem anteversion in the multivariate analysis. Second, all the patients of the current study

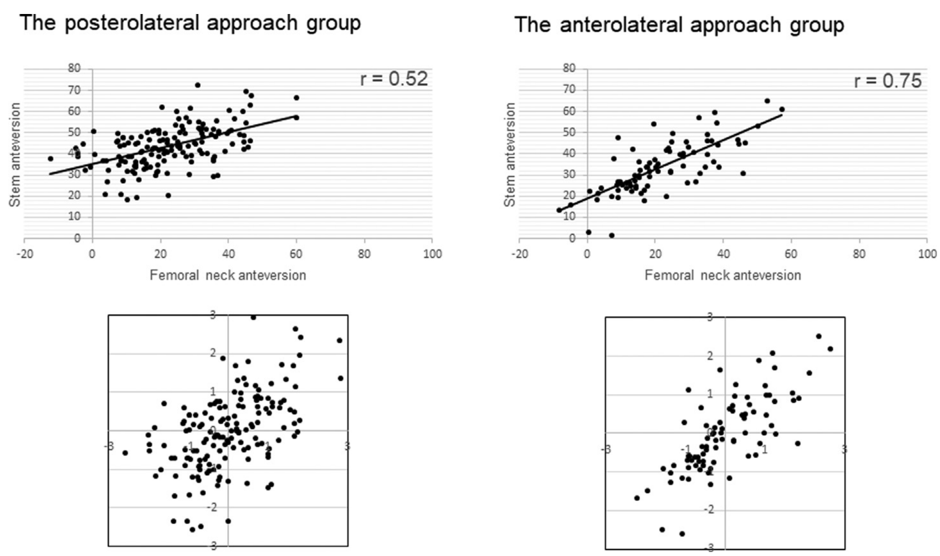

Fig. 2. Correlation between stem anteversion and femoral neck anteversion. Scatter and standardized scatter diagrams showing the positive correlation between stem anteversion and femoral neck anteversion in the posterolateral and anterolateral groups. The correlation in the anterolateral group ($r = 0.75$; $p < 0.01$) was stronger than that in the posterolateral group ($r = 0.52$; $p < 0.01$).

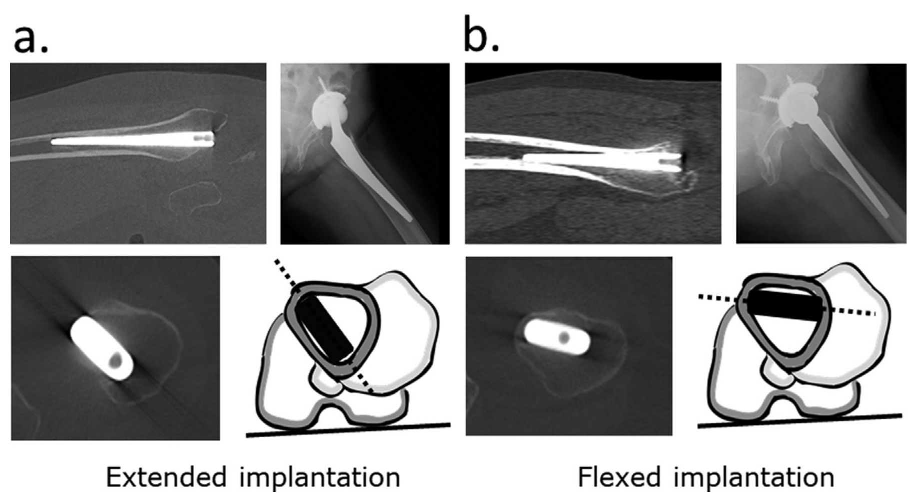

Fig. 3. Stem anteversion in the extended or flexed implantation. Image showing the stem position in the lateral and axial views in the cases with extended implantation (a) or flexed implantation (b). (Above) Lateral view of the femur in the CT image (left) and radiographic image (right). (Below) Axial view of the femur in the CT image (left) and drawing (right). The stem anteversion, which was the angle formed by the stem neck major axis (dotted line) and the femoral posterior condylar line (solid line), is larger in the extended implantation (a) than in the flexed implantation (b).

had osteoarthritis due to hip dysplasia. In Japan, more than 90% of hip osteoarthritis reportedly result from hip dysplasia [10,11]. The femoral neck anteversion in hip dysplasia is greater than that in other etiologies. Therefore, although cases with excessive anteversion were excluded in this study, the results might be slightly different for those cases. Finally, only a tapered wedge stem was evaluated. Other types of stems, including a metaphyseal filling stem, a cylindrical type stem, and a cemented stem were not evaluated, and results might differ in other stem types as the previous study using an anatomical stem.

To our knowledge, only one study has reported on the difference in anteversion increase among different approaches. Abe et al. [8] conducted a comparative study of anteversion increase measured on CT with an anatomical stem. They found no significant difference in the anteversion increases between the PLA ($3.0^\circ \pm 8.4^\circ$) and DAA ($5.5^\circ \pm 8.5^\circ$) groups, which can be explained by stem geometry. Tapered wedge stems are stabilized using a metaphyseal press-fit, while anatomical stem stability relies on proximal endosteal geometry [23]. Consequently, the anteversion of the anatomical stem is strongly dependent on the native femoral neck anteversion. In this study, we found that the surgical approaches using a tapered wedge stem affected the stem anteversion, anteversion increase, cup anteversion, and CA. We believe that it is useful to know that the difference in the stem anteversion between PLA and ALA leads to different CA.

The appropriate cup anteversion for avoiding prosthetic impingement is dependent on various stem anteversion [18]. According to Widmer's theory, which proposed an appropriate CA, the acceptable range of the stem anteversion is considerably limited if the cup inclination angle is set around 40°. In this study, cases with femoral anteversion from −15 to 60° were included. Although there were no cases of postoperative dislocation in this study, the acceptable range of the preoperative femoral anteversion may have to be more limited if the hip is to be reconstructed using a non-modular tapered wedge stem.

This study showed that the femoral neck and stem anteversions were correlated positively in both the approaches, and the correlation was stronger in the ALA than in the PLA. The tapered wedge stem is thin antero-posteriorly; thus, the influence of the endocortical bone to the tapered wedge stem position is relatively small, and the degree of freedom of rotation is high. The stem implantation through the ALA is thought to be more restricted than that through the PLA due to the difference of difficulty in femoral exposure. Consequently, the anteversion of the stem inserted through the ALA was restored more anatomically than that through the PLA in cementless THA using a tapered wedge stem. As such, excessive large stem anteversion might have been avoided in ALA. Therefore, in THA using a tapered wedge stem, surgeons should keep in mind that a tapered wedge stem anteversion is susceptible to surgical approaches.

5. Conclusion

Using the tapered wedge stems, the stem anteversion was correlated with femoral neck anteversion. However, it was influenced by the type of approaches. Stem implantation through the ALA allowed for a more anatomic restoration of femoral anteversion than through the PLA.

Disclosure of interest

The authors declare that they have no competing interest.

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Author's contribution

NT: conceived and designed the study; collected, analysed, and interpreted the data; drafted, revised, and approved the manuscript.

TJ: conceived and designed the study; collected, analysed, and interpreted the data; revised the manuscript critically for important intellectual content and approved the manuscript.

DK: conceived and designed the study; collected, analysed, and interpreted the data; revised and approved the manuscript.

SO: collected, analysed, and interpreted the data; revised and approved the manuscript.

AO: revised and approved the manuscript.

HH: revised and approved the manuscript.

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