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# Impingement-free Range of Motion After Total Hip Arthroplasty with A Cup-First Technique Using a CT Navigation System

**Ryo Hidaka[1], Shigeru Nakamura[1*], Masaki Nakamura[2], Shiho Kanezaki[1], Hanae Nishino[2], Masuhiro Tamayama[2]**

[1]Department of Orthopaedic Surgery, Teikyo University Mizonokuchi Hospital, Japan

[2]Department of Orthopaedic Surgery, Teikyo University Hospital, Japan

[*]**Corresponding author:** Shigeru Nakamura, Teikyo University Mizonokuchi Hospital, Department of Orthopaedic Surgery, 5-1-1, Futago, Takatsu-ku, Kawasaki, Kanagawa, 213-8507, Japan. Tel: +81448443333; Fax: +81448443252; E-mail: nakamura@med.teikyo-u.ac.jp

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## Abstract

Background. Accurate placement of the components in Total Hip Arthroplasty (THA) is important for obtaining a good Impingement-Free Range of Motion (IF-ROM). The usefulness of navigation for obtaining good IF-ROM has been reported only with a stem-first technique. This study evaluated the usefulness of THA with a cup-first technique using a Computed Tomography (CT)-based navigation system for obtaining good IF-ROM. Methods. We retrospectively reviewed 51 hips in 50 patients who underwent cementless primary THA using a CT-based navigation system for only implantation of the cup. Preoperative planning was done using three-dimensional template software. The target cup orientation was determined using a combined anteversion formula. IF-ROM was evaluated using postoperative CT data. Results. Forty-five hips (88%) met all IF-ROM benchmarks. Six hips did not reach the benchmark in one direction of IF-ROM. All the hips reached the benchmark for flexion, 96% for internal rotation at 90° of flexion, and 92% for external rotation at 0° of hip flexion, and 100% for hip extension. Conclusion. The proportion of patients that achieved good IF-ROM using a cup-first technique was equivalent to that reported for the stem-first technique. CT-based navigation with a cup-first technique is useful for acquiring good IF-ROM in THA.

**Keywords:** Cup-First Technique; CT Navigation; Impingement-Free Range of Motion; Total Hip Arthroplasty

## Abbreviations:

| | | |
|---|---|---|
| AA | : | Anatomic Anteversion |
| CA | : | Combined Anteversion |
| CT | : | Computed Tomography |
| IF-ROM | : | Impingement-Free Range of Motion |
| RA | : | Radiographic Anteversion |
| RI | : | Radiographic Inclination |
| SA | : | Stem Antetorsion |
| THA | : | Total Hip Arthroplasty |

## Introduction

In patients who undergo Total Hip Arthroplasty (THA), impingement of the metal femoral neck on the cup liner can lead to instability, accelerated wear of the polyethylene liner, and pain [1,2]. Such impingement can be avoided by appropriate preoperative planning and correct orientation of the implants. Combined Anteversion (CA) is one of the parameters used when orienting the cup and stem in THA. Several formulae have been proposed for calculation of the ideal CA allowing optimal Impingement-Free Range of Motion (IF-ROM) at the hip [3,4]. Widmer [3] defined the benchmark for IF-ROM as flexion ≥130°, internal rotation ≥80°, external rotation ≥40°, extension ≥40°, abduction ≥50°, and adduction ≥50°. They proposed the ideal CA formula when the Radiographic Inclination (RI) of the cup is between 40° and 45° to be as follows: cup Radiographic Anteversion (RA) + 0.7 × Stem

Antetorsion (SA) = 37.3°. However, Yoshimine [4] defined the benchmark for IF-ROM as flexion >120°, internal rotation >45° at flexion of 90°, external rotation >40° at flexion of 0°, and extension >30°, and proposed the optimal CA formula to be as follows: cup Anatomic Anteversion (AA) + cup RI + 0.8 × SA = 90.8°.

To obtain the planned CA with high reproducibility in cementless THA using a non-modular stem, one of the problems is that control of SA is restricted according to the configuration of the proximal femoral medullary canal. Renkawitz [5] studied the usefulness of an imageless navigation system in cementless THA using a stem-first technique when IF-ROM was a major outcome and reported that the IF-ROM benchmarks were achieved by more patients in the navigation group (84%) than in the control group (65%). However, the proportion of patients likely to achieve the IF-ROM benchmarks of THA with a cup-first technique using Computed Tomography (CT)-based navigation has not been reported. The purpose of this study was to evaluate the usefulness of THA with a cup-first technique using a CT-based navigation system to achieve a good IF-ROM.

## Material and Methods

This retrospective study was performed with institutional review board approval (approval number:15-152). One hundred and six cementless primary THAs were identified to have been performed using a CT-based navigation system (Stryker CT-Hip System V1.1, Stryker-Leibinger GmbH & Co. KG, Freiberg, Germany) at either of our two affiliated hospitals between September 2014 and May 2016. Exclusion criteria were: use of a modular stem (26 hips), use of components with an oscillation angle <135° (24 hips), use of non-flat liners (3 hips), and no postoperative CT scan data available (2 hips). The reason for exclusion of cases using components with an oscillation angle <135 was that we had used Yoshimine's formula [4] of CA developed under the condition of using components with an oscillation angle of no less than 135°. The remaining 51 hips (50 patients; 15 men, 35 women) were enrolled in the study.

The preoperative diagnosis was osteoarthritis in 37 hips, osteonecrosis in 11, rapidly destructive coxopathy in 2, and rheumatoid arthritis in 1. The acetabular component was a hemispheric cementless cup (SQRUM, Kyocera, Inc., Osaka, Japan [n = 23] or Continuum, Zimmer Biomet Holdings, Inc., Warsaw, IN [n = 28]). The acetabular liners were made of cross-linked polyethylene, and the shape was flat-type in all hips. The femoral head size was 28 mm in 13 hips, 32 mm in 33 hips, and 36 mm in 5 hips. The appropriate SA was calculated using three-dimensional template software (ZedHip, Lexi Co., Tokyo, Japan) on a CT scan before surgery. A modular stem (SROM-A, Depuy Synthes, Inc., West Chester, PA) was selected for hips with an anticipated SA of <10° or >40°. Non-modular stems were used in all the enrolled hips in anticipation of SA in the range of 10°-40°. A J-taper (Kyocera) stem were used in 23 hips, a Fitmore (Zimmer-Biomet) stem in 22, an Alloclassic (Zimmer-Biomet) stem in 3, and a Trabecular Metal (Zimmer-Biomet) stem in 3.

### Preoperative Planning

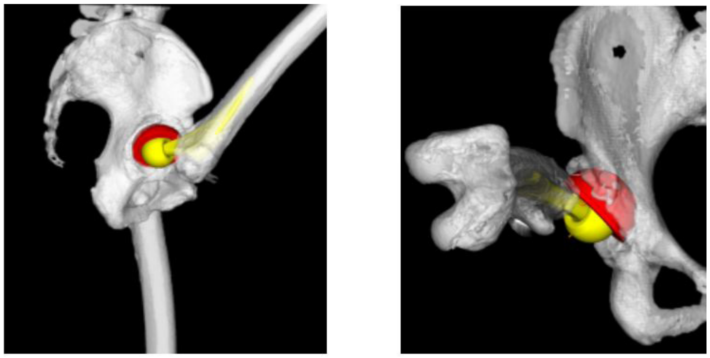
A preoperative CT scan extending from the iliac wing to the knee joint was obtained using a helical CT scanner (Light-speed VCT; GE Medical Systems, Milwaukee, WI). The slice thickness was 1.25 mm. The CT data were transferred to the ZedHip software for preoperative planning. The size and antetorsion of the stem were adjusted to match the shape of the proximal femoral medullary canal. The orientation of the cup was then decided. The target RI of the cup was determined to be 43° for all hips. Cup AA was calculated for each hip using Yoshimine`s CA formula [4]: cup RI + cup AA + SA × 0.8 = 90.8°. The planning data were inputted into the CT-based navigation system.

### Surgical Procedure

All operations were performed using a posterolateral approach with the patient in the lateral decubitus position. A pelvic tracker was fixed percutaneously on the ipsilateral ilium using two 4 mm pins and an external fixation device (Hoffman II, Stryker-Leibinger), and the surface matching of the pelvis was completed by digitizing more than 30 points around the acetabulum. The acetabular cup was implanted using the navigation system and the stem was placed without it. All surgeries were performed by either of the two Senior Authors (SN, MN).

### Postoperative Evaluation

A CT scan of the pelvis and both femurs was taken 1-2 weeks postoperatively using a minimal radiation dose protocol [6]. The postoperative CT data were transferred to the ZedHip software for three-dimensional analysis, and implant orientation and IF-ROM were measured. All preoperative planning and postoperative CT reference points were matched manually. The postoperative Yoshimine's CA was calculated from the implant orientation measurements. The difference between the target CA value (90.8°) and the postoperative value was defined as the error of CA. Yoshimine's CA includes two factors: a cup factor (RI + AA) and a stem factor (SA). The difference between the preoperative target value and the postoperative value was calculated and defined as the error for each respective factor. An absolute error of less than 10° was defined as good and outliers were defined as poor. IF-ROM was evaluated postoperatively using the ZedHip software (Figure 1).



(A) Flexion (B) Internal rotation at flexion of 90°

**Figure 1:** Calculation of IF-ROM. Three-dimensional surface models of the pelvis and femur were reconstructed from the postoperative computed tomography data, allowing IF-ROM to be calculated. (A) Flexion. (B) Internal rotation at flexion of 90°. IF-ROM, impingement-free range of motion

Yoshimine's stringent criteria (flexion >120°, internal rotation >45° at flexion of 90°, external rotation >40° at flexion 0°, and extension >30°) [4] were used to calculate the proportion of hips that fulfilled all IF-ROM benchmarks. All hips were followed for at least 6 months, during which postoperative complications were recorded.

### Statistical Analysis

The categorical data were analyzed using Fisher`s exact test. A P-value <.05 was considered statistically significant.

## Results

The mean Yoshimine's CA value was 89.2° ± 6.8° (range 76.1°-109.5°) and the mean absolute error for CA was 5.7° ± 3.9° (range 0.1°-18.7°). The accuracy of CA was deemed to be good for 44 hips (86%) and poor for 7 hips. The mean absolute error for the cup factor was 4.2° ± 3.2° (range 0.1°-12.2°). The accuracy of cup placement was determined to be good for 48 hips (94%) and poor for 3 hips (6%). The mean absolute error for the stem factor was 4.9° ± 3.6° (range 0.2°-15.5°) and the accuracy of the stem placement was good for 48 hips (90%) and poor for 5 hips (10%). The mean (range) values for IF-ROM are shown in (Table 1).

| | IF-ROM | Hips in the outlier region |
|---|---|---|
| Flexion | 137.3 ± 9.0 (122-159) | 0 |
| Internal rotation at 90° flexion | 59.5 ± 9.7 (35-82) | 2 |
| External rotation at 0° flexion | 47.6 ± 8.6 (32-70) | 4 |
| Extension | 56.6 ± 12.8 (29-88) | 0 |

IF-ROM data are shown as the mean and standard deviation and the hips in the outlier region as the number. **IF-ROM:** Impingement-Free Range of Motion.

**Table 1:** Mean impingement-free range of motion and number of hips in the outlier region.

One hundred percent of hips reached the benchmark for flexion, 96% for internal rotation at flexion of 90°, 92% for external rotation at flexion of 0°, and 100% for extension. Forty-five hips (88%) reached all IF-ROM benchmarks and six hips (12%) did not reach the benchmark in one direction of ROM. Two hips did not reach the ROM boundary (>45°) for internal rotation at flexion of 90° and four hips did not reach the ROM boundary (>40°) for external rotation at flexion of 0°. There was a significant correlation between IF-ROM and CA (P < .001) (Table 2).

| | IF-ROM | |
|---|---|---|
| **CA** | **Good** | **Poor** |
| Good (44) | 43 | 1 |
| Poor (7) | 2 | 5 |

P < .0001, Fisher's Exact test
IF-ROM: Impingement-Free Range of Motion; CA: Combined Anteversion.

**Table 2:** Impingement-free range of motion and combined anteversion.

Forty-three of 44 hips with good CA showed good IF-ROM. No instances of hip dislocation, surgical site infection, or pulmonary embolism were noted during follow-up.

## Discussion

Several studies have reported an ideal CA as the index for implant orientation in THA. Ranawat [7] recommended a CA in the range of 25°-45° (sum of cup and stem anteversion) and commented that women fare better with CA closer to 45° while men require only about 20°-30° of total anteversion for satisfactory function. Jolles [8] showed that the risk of dislocation was 6.9 times higher if the CA was not in the range of 40°-60°. Komeno [9] compared 20 dislocated hips with 18 non-dislocated hips using postoperative CT scans and reported that the mean CA was 47.8° in hips without dislocation, 27.4° in those with posterior dislocation, and 72.2° in those with anterior dislocation. Their results suggest that the CA influences the risk of dislocation. However, no dislocations occurred in our study population.

Several computer simulation studies have reported that an appropriate CA value is important for achievement of good IF-ROM. D'Lima [10] studied the effects of the positions of the acetabular and femoral components on impingement and ROM using a computer model and reported that acetabular abduction angles of 45°-55° with appropriate CA permitted good overall

ROM and stability. Hisatome [11] proposed that Widmer's CA should be 42° with a cup inclination of 45° and a head diameter of ≥32 mm to meet the following stringent ROM criteria: flexion >120°, extension >30°, internal rotation > 60° at 90° flexion, and external rotation >40° at neutral.

Some studies have investigated whether the CA value was achieved within the target range on the postoperative CT scan. Two studies evaluated the reproducibility of CA with a cup-first technique using a navigation system only for the cup. Wissilew [12] reported that 36/46 hips (78%) had a CA of 25°-50°, and Fukunishi [13] reported that 61/79 hips (77%) were within a Widmer's CA target of 37° (± 10°). Both these studies used an imageless navigation system. Our present study using CT-based navigation achieved a CA within the target range in 85% of cases, which is higher than that in the previous reports.

Native femoral anteversion has been reported to show wide interindividual variability [14-16]. Antetorsion of the cementless stem (SA) cannot be controlled because of the anatomy of the proximal femur. A broad range of postoperative SA values has been reported in the literature [16-18]. In the studies reported by Wassilew and Fukunishi [12,13], the target angle of cup anteversion was constant for all cases. This seems to be one of the reasons for the lower accuracy of CA. In the present study, the target cup anteversion was determined for each hip according to the SA predicted by Yoshimine's CA formula, and the proportion of hips with good CA was higher than in the prior studies.

Several studies have reported the usefulness of the stem-first technique using a navigation system for both the stem and cup. Dorr [19] reported achieving a mean postoperative CA of 37.6° ± 7.0° (range 19°-50°) and that a safe zone of 25°-50° was achieved in 45 (96%) of 47 hips. Fukunishi [20] compared patients who underwent primary THA using a cup-first or stem-first technique using the image-free navigation system and reported Widmer's CA values to be in the satisfactory range (37.0° ± 5.0°) in 41.9% of subjects in the cup-first group and 92.3% of those in the stem-first group. Therefore, THA using the stem-first technique could effectively achieve accurate and consistent control of the CA value. In a randomized controlled trial comparing the potential IF-ROM achieved by imageless-navigated THA with a stem-first technique or conventional THA, Renkawitz [5] defined the desirable ROM benchmarks for activities of daily living to be as follows: flexion >110°, internal rotation >30° at 90° hip flexion, extension >30°, external rotation >45° at flexion of 0°, abduction >50°, and adduction >30°. In that study, 48 (84%) of 57 hips in the stem-first group and 43 (65%) of 66 hips in the conventional THA group reached the benchmarks for all directions. However, it is necessary to insert two threaded pins in the distal femur when using CT-based navigation system on the stem, which is an additional surgical invasion. Kitada [21] reported that the clinical accuracy of the CT-based navigation system was lower for stem anteversion than for cup anteversion. Therefore, we used the navigation system only for the cup.

We did identify some problems in terms of the proportion of hips achieving the IF-ROM benchmarks using the cup-first technique with CT navigation. We found that 98% of hips with good CA reached the IF-ROM benchmarks, which suggests that the accuracy of CA is important. The CA includes both cup orientation and SA. We found a higher proportion of outliers for SA than for cup orientation. Therefore, it is probable that the main problem is the reproducibility of SA.

Two studies [22,23] have reported a strong correlation between SA in preoperative planning using three-dimensional template software and SA on postoperative CT. However, there were some hips with absolute errors of >10° in those studies. Inoue [23] reported that the absolute error in stem anteversion was 4.0° ± 3.6° and that 9% (6/65 hips) had absolute errors of >10°. In our study, the absolute error in non-modular SA was 4.9° ± 3.6°, and 10% (5/51 hips) had absolute errors of >10°. In the study reported by Inoue [23], a short fit-and-fill anatomic stem was used, whereas we mainly used a single taper wedge stem in the present study. A single taper-wedge stem seems to allow a greater degree of adjustment of SA than an anatomic stem. Further research is needed to determine the effects of stem design on the reproducibility of SA.

There are several limitations to this study. First, measurement errors in the three-dimensional template software used should be considered. Inoue [23] stated that measurement errors might occur using this software when manually matching reference points between the preoperative plan and the postoperative evaluation on CT. Second, our study did not evaluate the sagittal alignment of the stem. Two studies have reported that sagittal alignment of the stem had an influence on IF-ROM [24,25]. Third, a variety of head sizes and implant designs were included. These have an important impact on the impingement-free range of motion. The further study in a randomized prospective fashion should be considered to improve the strength of the study.

## Conclusion

The cup-first technique using a CT-based navigation system is useful for achieving a good IF-ROM.

## References


1. Malik A , Maheshwari A, Dorr LD (2007) Impingement with total hip re-place-ment. J Bone Joint Surg Am 89: 1832-1842.

2. Shon WY, Baldini T, Peterson MG, Wright TM, Salvati EA (2005) Impingement in total hip arthroplasty a study of retrieved acetabular components. J Arthroplasty 20: 427-435.

3. Widmer KH and Zurfluh B (2004) Compliant positioning of total hip components for optimal range of motion. J Orthop Res 22: 815-821.

4. Yoshimine F (2006) The safe-zones for combined cup and neck anteversions that fulfill the essential range of motion and their optimum combination in total hip replacements. J Biomech 39: 1315-1323.

5. Renkawitz T, Weber M, Springorum HR, Sendtner E, Woerner M, et al.(2015) Impingement-free range of movement, acetabular component early clinical results comparing 'femur-first' navigation and 'conventional' minimally invasive total hip arthroplasty: a randomised controlled trial. Bone Joint J 97: 890-898.

6. Arai N, Nakamura S, Matsushita T, Suzuki S (2010) Minimal radiation dose computed tomography for measurement of cup orientation in total hip arthroplasty. J Arthroplasty 25: 263-267.

7. Ranawat C, Maynard M (1991) Modern technique of cemented total hip arthroplasty. Techniques in Orthopaedics 6: 17-25.

8. Jolles BM, Zangger P, Leyvraz PF (2002) Factors predisposing to dislocation after primary total hip arthroplasty. The Journal of Arthroplasty 17: 282-288.

9. Komeno M, Hasegawa M, Sudo A, Uchida A (2006) Computed tomographic evaluation of component position on dislocation after total hip arthroplasty. Orthopedics 29: 1104-1108.

10. D'Lima DD, Urquhart AG, Buehler KO, Walker RH, Colwell CW Jr. (2000) The effect of the orientation of the acetabular and femoral components on the range of motion of the hip at different head-neck ratios. J Bone Joint Surg Am 82: 315-321.

11. Hisatome T, Doi H (2011) Theoretically optimum position of the prosthesis in total hip arthroplasty to fulfill the severe range of motion criteria due to neck impingement. J Orthop Sci 16: 229-237.

12. Wassilew GI, Perka C, Koenig C, Janz V, Asbach P, et al. (2010) 3D CT analy-sis of combined cup and stem anteversion in cases of cup navigation in hip arthroplasty. Orthopedics 33: 48-51.

13. Fukunishi S, Fukui T, Nishio S, Fujihara Y, Okahisa S, et al. (2012) Combined anteversion of the total hip arthroplasty implanted with image-free cup navigation and without stem navigation. Orthop Rev (Pavia) 4: 33.

14. Sugano N, Ohzono K, Nishii T, Haraguchi K, Sakai T, et al. (2010) Computed-Tomography-Based Computer Preoperative Planning for Total Hip Arthroplasty. Computer Aided Surgery 3: 320-324.

15. Husmann O, Rubin PJ, Leyvraz, PF, , de Roguin B, Argenson JN (1997) Three-dimensional morphology of the proximal femur. J Arthroplasty 12: 444-450.

16. Fujishiro T, Hayashi S, Kanzaki N, Hashimoto S, Kurosaka M, et al. (2014) Computed tomographic measurement of acetabular and femoral component version in total hip arthroplasty. Int Orthop 38: 941-946.

17. Wines AP, McNicol D (2006) Computed tomography measurement of the accuracy of component version in total hip arthroplasty. J Arthroplasty21:696-701.

18. Sendtner E, Tibor S, Winkler R, Wörner M, Grifka J, et al. (2010) Stem torsion in total hip replacement. Acta Orthop 81: 579-582.

19. Dorr LD, Malik A, Dastane M, Wan Z (2009) Combined anteversion technique for total hip arthroplasty. Clin Orthop Relat Res 467: 119-127.

20. Fukunishi S, Nishio S, Fujihara Y, Okahisa S, Takeda Y, et al. (2016) Accuracy of combined anteversion in image-free navigated total hip arthroplasty: stem-first or cup-first technique? Int Orthop 40: 9-13.

21. Kitada M, Nakamura N, Iwana D, Kakimoto A, Nishii T, et al. (2011) Evaluation of the Accuracy of Computed Tomography-Based Navigation for Femoral Stem Orientation and Leg Length Discrepancy. Journal of Arthroplasty 26: 674-679.

22. Sariali E, Mouttet A, Pasquier G, Durante E, Catone Y (2009) Accuracy of reconstruction of the hip using computerised three-dimensional pre-operative planning and a cementless modular neck. J Bone Joint Surg Br 91: 333-340.

23. Inoue D, Kabata T, Maeda T, Kajino Y, Fujita K, et al. (2015) Value of computed tomography-based three-dimensional surgical preoperative planning software in total hip arthroplasty with developmental dysplasia of the hip. J Orthop Sci 20: 340.

24. Renkawitz T, Haimerl M, Dohmen L, Gneiting S, Lechler P, et al. (2012) The association between Femoral Tilt and impingement-free range-of-motion in total hip arthroplasty. BMC Musculoskeletal Disorders 13: 1.

25. Müller M, Duda G, Perka C, Tohtz S (2016) The sagittal stem alignment and the stem version clearly influence the impingement-free range of motion in total hip arthroplasty: a computer model-based analysis. Int Orthop 40: 473-