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# Acetabular Component Positioning in Total Hip Arthroplasty: An Evidence-Based Analysis

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**Abstract:** Advocates for navigated (NAV) total hip arthroplasty (THA) emphasize the potential for improved component placement. We reviewed published literature to investigate the claim of increased precision of acetabular component placement in navigated THA compared to conventional (N-NAV) THA. Major medical and publishers' databases were searched, making no restrictions for study type, yet restricting results to English-language sources. Nine studies of varying methodological quality involving 1479 THA with a mean age of 59.10 years were included. There was no statistically significant difference in mean acetabular component abduction and anteversion angles between the NAV and N-NAV groups. There was a statistically significant difference in the incidence of acetabular component placement in the "safe zone," with NAV having significantly more "safe placements" than N-NAV, regardless of the chosen safe zone. In addition, NAV had significantly fewer dislocations than N-NAV. These outcomes demonstrate the possible patient benefit from navigation and resulting tighter control of component position.
**Keywords:** acetabular component precision, dislocation, navigation, total hip arthroplasty, safe-zone placement.


Acetabular component orientation is a significant factor in the short-term and long-term outcomes of total hip arthroplasty (THA) [1]. Improper orientation negatively impacts dislocation rates, component impingement, bearing surface wear, survivorship, and revisions in the long term [2-5]. The acetabular component orientation, as defined by abduction and anteversion angles, is a major factor influencing dislocation [6]. The "safe zone" for orientation, as defined by Lewinnek et al [7] to be 15° ± 10° anteversion and 40° ± 10° lateral opening, has been in use for more than 3 decades. McCollum and Gray [8] suggest a safe zone of acetabular cup orientation using an abduction angle range of 30° to 50° and a flexion angle range of 20° to 40° from the horizontal plane to prevent impingement and dislocation.

Despite the implementation of either targeted safe zone, recent research of Medicare data has demonstrated dislocation rates during the first 6 months after THA to range from 3.1% to 3.9% for primary THA performed for indications other than fracture and to range from 2.6% to 14.4% for revision THA [9,10]. Acetabular orientation also contributes to leg-length discrepancy, poor hip biomechanics, pelvic osteolysis, bearing wear, and acetabular component migration [11-13]. Leg-length discrepancy and dislocation are of particular concern in the immediate and intermediate postoperative period because they present significant concerns and costs to patients, surgeons, and society through longer hospital stays, increased medical care, additional surgical procedures, and increased litigation because of patient dissatisfaction [1,14-24]. In addition, survivorship of alternative bearings (hard-on-hard, or hard-on–highly cross-linked polyethylene) and hip resurfacing have also been linked to acetabular component placement; these bearings are even less tolerant of component malposition than are metal-on-ultra high molecular weight polyethylene (UHMWPE) (hard-on-soft) [9,23,25].

The numbers of THA procedures performed in the United States are projected to rise dramatically; the number of revision surgeries is expected to double between 2005 and 2026, and by 2030, there are 572 000 primary and 96 700 revision THA surgeries expected [26]. Appropriate acetabular component orientation is a factor in decreasing the incidence and prevalence of additional hip procedures and revision THA; in the coming years, its importance is thus expected to continue to grow.

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# Methods

Procedures for this review followed established best methods for the evolving science of systematic review research and evidence-based medicine [27,28]. The objectives, search criteria, study selection criteria, data elements of interest, and plans for analysis were defined in a written protocol before beginning this evidence-based analysis.

## Search Strategy

English language literature from January 1, 1990, to February 15, 2010, was searched using 7 online databases: (1) Scirus—PubMed, ScienceDirect, and MEDLINE; (2) PubMed; (3) Clin Orthop Rel Res archives; (4) Clin Orthop Rel Res 2007 forward; (5) *Journal of Arthroplasty*; and (6) and (7) *Journal of Bone and Joint Surgery*, American and British volumes. Due to varying search capabilities and term preferences inherent to each system, the exact set of search terms differs for the online databases; in general, navigated (NAV) THA, computer-assisted THA, and computer-aided THA were used as search terms. References from the resulting sources were checked to supplement electronic searches and to identify any additional sources.

## Inclusion Criteria

Included studies had to satisfy all of the following criteria: (1) computer-aided surgery (CAS) NAV primary THA compared to conventional (N-NAV) primary THA, (2) reporting of postoperative acetabular component alignment, and (3) at least 8 subjects in each treatment group. Rejection of possible sources required agreement of both authors. Any study design was acceptable for inclusion: both randomized controlled trials (RCTs), prospective and retrospective non-RCTs (nRCTs), and uncontrolled case series. Multiple publications of the same population were pooled as 1 study (kinship) to the extent possible to avoid double-counting cases and creating undue bias in data set.

All eligible studies were rated for level of evidence at the time of data extraction based on the Centre for Evidence-Based Medicine (Oxford, UK) guidelines [29]. Three reviewers (J.T.M., S.G.C., and L.F.) extracted data elements from the included studies. Differences were resolved before data entry and analysis through consensus.

## Outcome Measures

This evidence-based analysis is focused on acetabular placement and dislocation rate; the complication most likely to result from malalignment and/or component malposition.

## Statistics

All calculations were performed using JMP Statistical Analysis Software version 7.0.1 (SAS Software, Cary, NC) using contingency analysis or 1-way analysis with a significance level of .05. Outcomes of interest were postoperative acetabular component alignment in abduction and anteversion and the rate of dislocation. Numbers of acetabular components in safe-zone alignment (abduction, anteversion, or both), regardless of safe zone definition, were also captured. Actual measures of mean abduction and anteversion angles were captured when available. Study, patient, and treatment characteristics were summarized using basic descriptive statistics. For baseline patient characteristics, the number of patients enrolled (or randomized) was used as the denominator. For alignment outcomes, the number of hips evaluated for each alignment outcome was used in the analysis.

# Results

## Literature Search

The searches yielded 738 citations, of which 13 full publications were retrieved for further review. Four of these did not contain data useful for this analysis [1,30-32]. A total of 9 publications met all inclusion criteria and contained data that could be mined for this evidence-based analysis [33-41].

**Table 1.** Demographic Baseline Data

| | NAV | | | | N-NAV | | | |
|---|---|---|---|---|---|---|---|---|
| Author | N | Age (y), mean (range) | Male patients, n | Primary diagnosis, osteoarthritis, n | N | Age (y), mean (range) | Male patients, n | Primary diagnosis, osteoarthritis, n |
| Haaker | 98 | 66.9, (42-81) | 35 | – | 69 | 63.4, (47-77) | 26 | – |
| Kalteis | 30 | 63.9, (50-79) | 18 | – | 30 | 64.7, (50-79) | 13 | – |
| | 30 | 63.1, (50-77) | 12 | – | | | | |
| Lazovic | 127 | – | – | – | 110 | – | – | – |
| Mainard | 42 | 63.3, (–) | 18 | 37 | 42 | 60.5, (–) | 22 | 36 |
| Murphy | 185 | 56.1, (19-85) | 98 | 146 | 189 | 50.4, (21-78) | 94 | 121 |
| Najaran | 49 | 64, (–) | – | – | 53 | 65, (–) | – | – |
| | 47 | 65, (–) | – | – | | – | | |
| Parratte | 30 | 61.2, (24-80) | 16 | 27 | 30 | 62.6, (36-78) | 16 | 26 |
| Sugano | 59 | 53, (37-74) | 7 | 55 | 111 | 53, (27-72) | 20 | 98 |
| Wixson | 82 | 64, (24-89) | 42 | 74 | 50 | 62, (20-86) | 21 | 44 |

(–) indicates data not available.

**Table 2.** Study Characteristics

| | NAV | | | N-NAV | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| Study Characteristics | K | T | N | K | T | N | K | T | N |
| Totals | 9 | 11 | 784 | 9 | 9 | 695 | 9 | 20 | 1479 |
| Geographic location | | | | | | | | | |
| North America | 1 | 2 | 100 | 1 | 1 | 55 | 1 | 3 | 155 |
| Europe | 4 | 5 | 259 | 4 | 4 | 212 | 4 | 9 | 471 |
| Asia | 1 | 1 | 60 | 1 | 1 | 120 | 1 | 2 | 180 |
| Not reported | 3 | 3 | 365 | 3 | 3 | 308 | 3 | 6 | 673 |
| Setting | | | | | | | | | |
| Single center | 5 | 6 | 319 | 5 | 5 | 332 | 5 | 11 | 651 |
| Multicenter | 1 | 2 | 100 | 1 | 1 | 55 | 1 | 3 | 155 |
| Not reported | 3 | 3 | 365 | 3 | 3 | 308 | 3 | 6 | 673 |
| Institution category | | | | | | | | | |
| Teaching | 4 | 6 | 250 | 4 | 4 | 235 | 4 | 10 | 485 |
| Not reported | 5 | 5 | 534 | 5 | 5 | 460 | 5 | 10 | 994 |
| Study design | | | | | | | | | |
| RCT (level II) | 2 | 3 | 90 | 2 | 2 | 60 | 4 | 5 | 150 |
| nRCTs (level III) | 7 | 8 | 694 | 7 | 7 | 635 | 7 | 15 | 1329 |
| Industry sponsorship | | | | | | | | | |
| No | 1 | 1 | 30 | 1 | 1 | 30 | 1 | 2 | 60 |
| Yes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Not reported | 8 | 10 | 754 | 8 | 8 | 665 | 8 | 18 | 1419 |

K indicates number of studies; T, number of treatment groups; N, number of THAs.

## Study Characteristics

The final extracted and analyzable data set consists of 9 direct comparison studies of NAV and N-NAV THA studies from 1998 to 2010 and includes 20 treatment arms and 1479 THAs (Tables 1 and 2). Two studies, both RCTs, were rated as level II evidence, and the other 7 studies, nRCTs, were rated as level III evidence. Predominantly, studies were from Europe and primarily single centers. Choice of implants and cementing technique was highly variable across the studies when reported. Patient characteristics were not consistently reported; for studies reporting patient characteristics, the mean overall age of the patient population was 59.10 years (range, 19-89 years), mean body mass index was 27.05 kg/m$^2$ (range, 16-49.9 kg/m$^2$), 57.87% were male, and the most common disease indication for surgery was osteoarthritis at 80.00% of the population. The NAV group had significantly more patients with osteoarthritis as the primary indication for THA; otherwise, there were no significant differences in patient characteristics. In general, the 2 groups were well matched (Table 3).

## Outcome Measures

Acetabular component alignment analysis looked at mean abduction and anteversion angles, percentage of cup placements in abduction and anteversion safe zones, and dislocation rates (Table 4). There was no significant difference in either mean abduction angle or mean anteversion angle. The 95% confidence intervals (CIs) indicate a tighter control on abduction and anteversion angles for NAV than for N-NAV (abduction angle: NAV

**Table 3.** Patient Characteristics

| | NAV | | | N-NAV | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Characteristic | T | N | Mean (range) | T | N | Mean (range) | T | N | Mean (range) | *P*-value |
| Age (y) | 10 | 657 | 61.06 (19-89) | 8 | 585 | 56.91 (20-86) | 18 | 1242 | 59.10 (19-89) | .1398 |
| Body weight (kg) | 2 | 245 | 74.24 (36-129) | 2 | 309 | 72.55 (35-136) | 4 | 554 | 73.30 (35-136) | .9356 |
| BMI (kg/m$^2$) | 9 | 559 | 27.20 (17-43) | 7 | 516 | 26.88 (16-50) | 16 | 1075 | 27.05 (16-50) | .7700 |
| Height (cm) | 2 | 245 | 167.59 (140-193) | 2 | 309 | 164.79 (140-198) | 4 | 554 | 166.03 (140-198) | .8236 |
| | T | n/N | % | T | n/N | % | T | n/N | % | Pearson *P* |
| Sex | | | | | | | | | | .1645 |
| Male | 7 | 311/557 | 55.83 | 7 | 318/530 | 60.00 | 7 | 629/1087 | 57.87 | |
| Female | 7 | 246/557 | 44.17 | 7 | 212/530 | 40.00 | 7 | 458/1087 | 42.13 | |
| Disease indication | | | | | | | | | | .0004 |
| Osteoarthritis | 5 | 339/399 | 84.96 | 5 | 325/431 | 75.41 | 5 | 664/830 | 80.00 | |
| Other | 5 | 60/399 | 15.04 | 5 | 106/431 | 24.59 | 5 | 166/830 | 20.00 | |

BMI indicates body mass index; range, range of means.

**Table 4.** Acetabular Component Alignment Outcomes Meta-Analysis

| | NAV | | | N-NAV | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| Acetabular Alignment | T | N | Mean (range) (95% CI) | T | N | Mean (range) (95% CI) | T (N) | Mean (range) (95% CI) | Fisher *P* |
| Abduction (degrees) | 10 | 652 | 42.65 (4.48-58) (40.99-44.31) | 8 | 574 | 43.57 (24-64) (40.03-47.11) | 18 (1226) | 43.08 (4.48-64) (41.46-44.71) | .5686 |
| Anteversion (degrees) | 7 | 407 | 20.11 (5-38) (16.02-24.20) | 6 | 355 | 20.24 (2-53) (13.35-27.13) | 13 (762) | 20.17 (2-53) (16.98-23.36) | .9672 |
| | T | n/N | % | T | n/N | % | T (N) | Odds ratio (95% CI) | |
| Abduction safe zone | 5 | 445/490 | 90.82 | 4 | 348/402 | 86.57 | 9 (892) | 1.53 (1.01-2.33) | .0444 |
| Anteversion safe zone | 5 | 344/403 | 85.36 | 4 | 211/282 | 74.82 | 9 (685) | 1.96 (1.33-2.88) | .0005 |
| In both safe zones | 4 | 130/161 | 80.75 | 3 | 115/183 | 62.84 | 7 (344) | 2.48 (1.51-4.06) | .0003 |
| Complications | | | | | | | | | |
| Dislocations | 10 | 8/779 | 1.03 | 8 | 7/684 | 2.49 | 18 (1463) | 0.41 (0.17-0.95) | .0317 |
| Infections | 10 | 1/779 | 0.13 | 8 | 3/684 | 0.44 | 18 (1463) | 0.29 (0.03-2.81) | .2569 |
| Thrombosis | 10 | 0/779 | 0 | 8 | 0/684 | 0 | 18 (1463) | – | – |
| Embolism | 10 | 0/779 | 0 | 8 | 0/684 | 0 | 18 (1463) | – | – |

95% CI, 40.99-44.31, and N-NAV 95% CI, 40.03-47.11; anteversion angle: NAV 95% CI, 16.02-24.20, and N-NAV 95% CI, 13.35-27.13). The NAV group had significantly more acetabular components in the abduction safe zone (NAV, 90.82%; N-NAV, 86.57%; $P$ = .0444), in the anteversion safe zone (NAV, 85.36%; N-NAV, 74.82%; $P$ = .0005), and in both safe zones (NAV, 80.75%; N-NAV, 62.34%; $P$ = .0003) than the N-NAV group. Dislocation rates are believed to be closely related to acetabular component positioning; the NAV group had significantly fewer dislocations, 1.03%, than the N-NAV group, 2.49% ($P$ = .0317). There was no significant difference in infection rates. Other complications were so infrequently reported that no statistical comparisons could be conducted.

## Discussion

In 2007, Dorr et al [42] compared the precision and bias of imageless computer navigation and surgeon estimates for acetabular component position in 131 hips. In the first phase, postoperative computed tomography scans of 30 hips were used to determine computer-navigation values for inclination and anteversion of the acetabular cup. In the second phase, 101 hips, surgeons' blind estimates for trial cup position was compared to computer-navigation values. The computer navigation precision was better than the surgeon precision. The imageless navigation system was found to be accurate within 5° of the true value (4.4° for inclination and 4.1° for anteversion). The experienced surgeon's precision was 11.5° for inclination and 12.3° for anteversion.

This systematic review combines the results of available evidence from prospective RCTs and prospective nonrandomized comparative trials to determine whether primary THA with NAV or with N-NAV techniques provides more accurate placement of the acetabular component and thus, better outcomes. There is an obvious lack of prospective RCTs and poor congruency in data reporting; these are not uncommon problems in performing evidence-based analyses in joint arthroplasty. Because of the variability in study designs, outcomes are not always directly comparable. The authors chose to compare acetabular component alignment because it is not dependent on having long-term follow-up to examine this factor. In addition, dislocation rates were collected and analyzed because of their relationship with acetabular component alignment.

Although this evidence-based analysis did not find a statistically significant difference in NAV and N-NAV acetabular component placement, it is clear that final acetabular component angles are more tightly controlled with navigation. Acetabular components implanted with navigation are more often within either predetermined safe zone ($P$ < .0001), and dislocations are less likely to occur ($P$ = .0013). Because difficulties with acetabular component placement occur in outliers, patients may benefit from navigation and the resulting tighter control of component position. The authors feel that the results of this evidence-based analysis demonstrate a clear need for further prospective RCTs to define or determine the role of navigation in THA.

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