

Randomised controlled trial comparing 2 methods of acetabular cup positioning during total hip arthroplasty

P.-A. VENDITTOLI[1], M. GANAPATHI[1], N. DUVAL[2], P. LAVOIE[2], A. ROY[1], M. LAVIGNE[1]

[1] Orthopaedic Division, Department of Surgery, Maisonneuve-Rosemont Hospital, Montréal, Québec - Canada
[2] Pavillon des Charmilles, Laval, Québec - Canada

ABSTRACT: Background: *Acetabular cup positioning is an important technical aspect in total hip arthroplasty. Most surgeons estimate cup abduction angle during surgery with the insertion rod position according to the patient's body anatomical landmarks or other reference points in the operating room. High acetabular component abduction angle is associated with an increased risk of dislocation, premature polyethylene wear and osteolysis.*
Method: *To evaluate the potential benefits of a new technique for vertical acetabular cup positioning, 100 acetabular cups were randomised to be inserted with or without an inclinometer. Abduction angles were measured on postoperative radiographs by 2 evaluators blind to the treatment group.*
Results: *Of the cups, 57% (27/47) were positioned within the desirable abduction angle range of 40°-49° with the inclinometer, compared with 50% (27/53) by visuospatial perception (p=0.454). The proportion of cups positioned outside a safe angle range of 30°-55° was low in both groups: 6% (3/47) for the inclinometer group versus 4% (2/53) for the visuospatial perception group (p=0.536).*
Conclusion: *The use of an inclinometer did not significantly improve the acetabular cup abduction angle obtained by our group of surgeons when compared with visuospatial perception. Newer techniques such as navigation may be useful in further optimising cup positioning and reducing the outliers. (Hip International 2007; 17:)*

KEY WORDS: Abduction angle, Acetabulum, Hip prosthesis, Inclinometer

INTRODUCTION

Total hip arthroplasty is a very successful surgical procedure (1-3). However, a significant number of total hip arthroplasty revisions are performed every year, with many of them resulting from component malposition (4). Acetabular component malposition is associated with an increased risk of dislocation (5-7), limited range of motion, and impingement (8-11). A high abduction angle of the acetabular cup correlates positively with premature polyethylene wear, osteolysis and early aseptic loosening in metal-polyethylene (12-16) and ceramic-ceramic interfaces (17, 18). The suggested explanation for this correlation is that a high abduction angle increases the articular load per unit of surface area (12, 14, 19-21), eventually leading to acetabular cup wear and superolateral migration of the femoral head. Many authors recommend positioning the acetabular cup within an abduction angle range of 30° to 50° (5, 7-9, 22-27).

It is common practice for orthopaedic surgeons to rely on their visuospatial perception (VSP) when positioning the acetabular component during total hip arthroplasty. Various referencing techniques are used including the cup insertion rod position, patient's anatomical landmarks and reference points in the operating room (operating table, wall, floor etc.) (5). However, previous studies have shown that positioning of the acetabular component by VSP is variable and

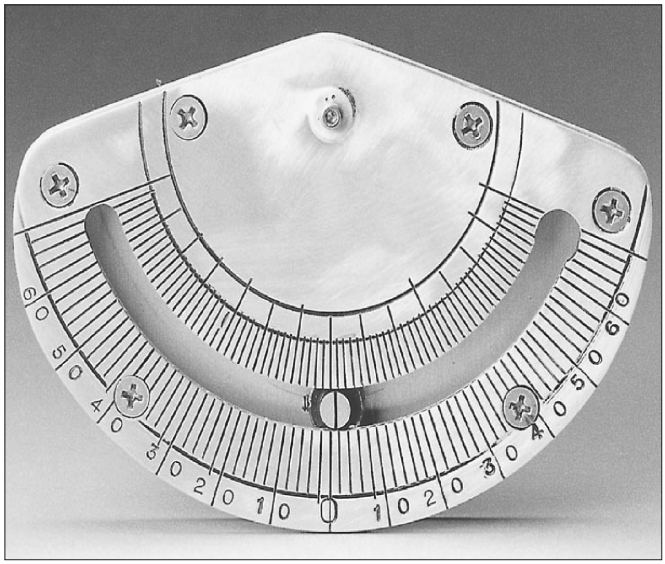

Fig. 1 - *Front view of the inclinometer.*

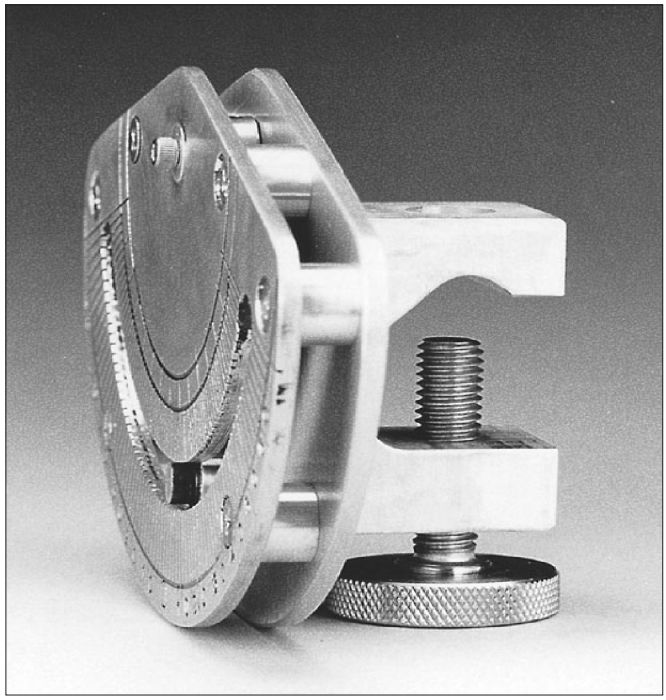

Fig. 2 - *Lateral view of the inclinometer.*

lacks precision (28-30).

In a previous cadaver study (30)[AUTHORS: please advise: correct edit?], we found that the positioning of the acetabular cup with reference to the abduction angle significantly improved when orthopaedic trainees used an inclinometer to aid positioning. The aim of the current study was to evaluate whether there would be a significant improvement in the cup abduction angle when the inclinometer was used by consultant surgeons in a clinical setting.

MATERIALS AND METHODS

The inclinometer (designed by PV)[AUTHORS: please advise: who is the manufacturer of this device and where was it obtained?] is made of steriliseable stainless steel and this can be attached to most acetabular insertion rods by hand-tightening a single screw. It is scaled at every 2° from 0 to 70°. Display of the abduction angle value results from displacement of the pendulum within the inclinometer over the inclinometer scale under the influence of gravity (Figs. 1 and 2). The inclinometer only measures the abduction angle; the anteversion is not measured by the device.

Seven consultant surgeons regularly performing total hip arthroplasty participated in the study. A block randomisation table was created for each surgeon using SPSS version 10.04 software (SPSS Inc, Chicago, IL, USA), and the results were kept in an opaque, sealed envelope. The study protocol was approved by the research ethics and scientific committees of our institution. All patients who participated in the study gave their written informed consent.

One hundred patients were randomised to have their acetabular component positioned either with the inclinometer or by VSP. All procedures were done in lateral position either through a posterior approach (5 surgeons) or direct lateral approach (2 surgeons). After routine acetabular preparation, the chosen acetabular cup was screwed to a standard insertion rod. For the VSP group, the acetabular cup was positioned by the surgeon's usual method without inclinometer. After cup fixation, surgeons recorded their estimation of the acetabular cup abduction angle. For the inclinometer group, the surgeons were asked to position the acetabular cup within an abduction angle of 40°-49° as measured by the inclinometer attached to the insertion rod. Once the cup was fixed, the abduction angle read on the inclinometer was recorded.

An anteroposterior radiograph of the pelvis taken postoperatively was used to measure the abduction angle of the

TABLE I - COHORT DETAILS OF BOTH GROUPS

	Visuospatial perception (n=53)	Inclinometer (n=47)	p Value
Side			
Right	31 (58%)	23 (49%)	0.3617
Left	22 (42%)	24 (51%)	
Preoperative vertical acetabular angle	45.3° (SD 7.1)	46.0° (SD 6.7)	0.612
Primary surgery	44 (83%)	41 (87%)	0.4493
Revision surgery	9 (17%)	6 (13%)	

Data are numbers (percentages), unless indicated otherwise.
SD = standard deviation.

cup according to the horizontal inter-teardrop line (31, 32). All measurements were made independently by 2 observers blinded to the treatment group. The average measurement of both observers was used for the analysis. Optimal positioning was defined as an abduction cup angle between 40° and 49° as determined from the postoperative radiographs. Outliers were defined as an abduction angle less than 30° or more than 55°. Precision was defined as the difference between the abduction angle estimated intraoperatively by either method and the abduction angle measured on postoperative radiographs.

TABLE II - NUMBER OF CUPS IMPLANTED BY EACH SURGEON

Surgeon number	Inclinometer	Visuospatial perception
1	11	12
2	8	10
3	6	7
4	9	11
5	6	9
6	5	4
7	2	0
Total	47	53

Statistical analysis

All statistical analyses were performed using SPS software (33). Proportions were compared by the Pearson chi-square test. Mean differences between the VSP and the inclinometer methods were evaluated by Student's *t*-test for equal variances. Comparison of variances was conducted by Levenes's test. The confidence intervals presented were 95%, and the significance level accepted was $p<0.05$ for all statistical analyses.

RESULTS

Both groups were comparable with regards to the type of surgery, operated side and preoperative native acetabular abduction angle (Sharp angle) (34) (Tab. I). The number of cup implantations per surgeon is presented in Table II.

In the VSP group, 51% (27/53) of cups were positioned within the optimal abduction angle range (40°-49°) compared with 57% (27/47) in the inclinometer group (p=0.454). There was no significant difference in the proportion of the outliers (<30°, >55°) between the 2 groups: 4% (2/53) in the VSP group and 6% (3/47) in the inclinometer group (p=0.536; Fig. 3). There was also no significant difference in the mean abduction angle between the 2 groups (Tab. III).

No significant difference was found in precision between the 2 methods: ±5.4° (standard deviation 4.7) for the VSP group and ±4.8° (standard deviation 4.8) for the inclinometer group (p=0.553). The mean differences between the abduction angle estimated peroperatively and the abduction angle measured on postoperative radiographs were -0.6° for the VSP group and -1.5° for the inclinometer group (p=0.550).

The 95% confidence interval of the ratio of the standard deviations for both methods showed that the VSP method was not more variable than positioning the cup with the inclinometer (p=0.880).

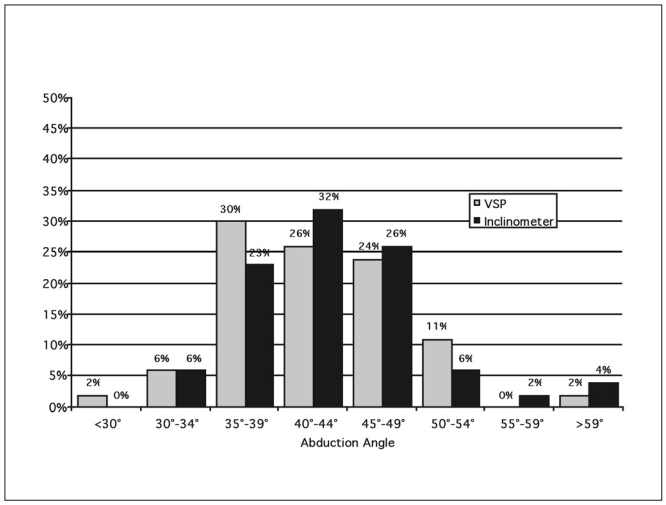

Fig. 3 - *Abduction angle of the acetabular cup in the current randomised controlled study with and without the use of the inclinometer. VSP = visuospatial perception.*

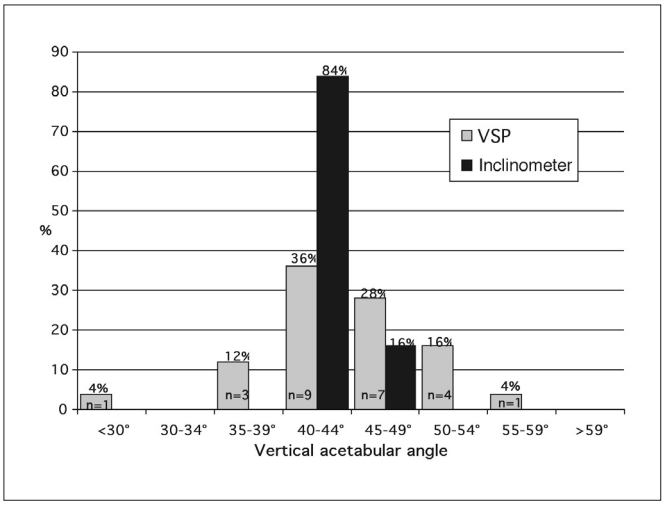

Fig. 4 - *Acetabular cup abduction angle in a previous cadaver study with and without the use of the inclinometer (30). VSP = visuospatial perception.*

DISCUSSION

As reported by Moran et al, orthopaedic surgeons are not always accurate in estimating angles (35). Suboptimal cup positioning has been reported in various studies (36-39). Many techniques have been developed to improve acetabular cup positioning. A commonly used technique involves attaching an alignment rod at 45° to the insertion rod (28) on the presumption that it is easier for surgeons to evaluate a 90° angle than a 45° angle. However, this was not substantiated in a previous study (28). The surgeons who participated in the current study did not use an alignment rod as part of their VSP technique.

Peroperative radiographic control is being used in some orthopaedic centres, especially with minimally invasive techniques. Disadvantages of this technique include increased risk of contamination, longer operating time and radiation exposure. Moreover, no study of the precision of this technique has ever been published. Another technique is a computer-assisted approach. Seki et al reported encouraging results with this approach, but it is time-consuming and requires a complex set-up that most orthopaedic centres cannot afford (25).

In a previous cadaver study, we found the use of an inclinometer on the insertion rod by orthopaedic trainees reduced the variability of acetabular cup abduction angle by a factor of 2.0-4.5 in comparison with VSP (Fig. 4) (30). There were no outliers in either group. In the current clinical study involving consultant orthopaedic surgeons, we found that the use of the inclinometer did not significantly improve the acetabular cup abduction angle when compared with VSP. This suggests that the VSP skills of orthopaedic surgeons improve with experience. The use of the inclinometer may help surgeons during the learning curve of their training and if they perform hip replacements infrequently.

The results of this study revealed that in both groups there was a greater tendency to underestimate the abduction angle intraoperatively. The mean difference between the peroperative angle measured and the postoperative ra-

TABLE III - ABDUCTION ANGLES MEASURED IN POSTOPERATIVE RADIOGRAPHS

Abduction angle	Visuospatial perception	Inclinometer	p Value
Mean	42.7°	43.6°	0.506
Standard deviation	6.7°	6.8°	
Minimum angle	27.5°	31.5°	
Maximum angle	63°	64°	

diographic angle was -1.5º with the inclinometer and -0.6º by VSP. This may be explained by the tendency of the pelvis to tilt caudally during the surgery. Particularly, when employing an inclinometer, the surgeon should pay special attention to vertical positioning of the patient's pelvis on the operating table, since this tool uses a pendulum oriented by gravity.

Acetabular cup positioning with regards to the abduction angle could be considered satisfactory in both groups in our study. However, there were still a small proportion of outliers (abduction angle less than 30° or more than 55°) in both groups (4% in the VSP group and 6% in the inclinometer group). This suggests that even when the cup positioning was done by experienced surgeons, neither VSP nor gravity-referenced devices like the inclinometer can completely eliminate the outliers. This is most probably due to the pelvic tilt in the coronal plane which can occur in the lateral decubitus position. Improvement in newer techniques such as navigation may help to eliminate such outliers in the future.

ACKNOWLEDGEMENTS

We thank all the surgeons who participated in this project: Luc Pilon, Julio Fernandes, Alain Roy, Robert Duchesnes, Martin Lavigne, Nicolas Duval and Pascal-A. Vendittoli. We acknowledge the editorial assistance of Ovid Da Silva, Éditeur-Rédacteur, Research Support Office, Research Centre, CHUM.

This study was partly presented as a poster ("Randomized study comparing 2 methods of acetabular positioning") at COA: Réunion Annuelle de l'Association d'Orthopédie du Canada, Calgary, 2004.

Financial support: None. Conflict of interest: None.

Address for correspondence:
Pascal-André Vendittoli, MD, MSC, FRCS(C)
5415 Boul L'Assomption
Montréal, Québec H1T 2M4, Canada
e-mail: pa.vendittoli@videotron.ca
pa_vendittoli@hotmail.com

REFERENCES

1. Kavanagh BF, Wallrichs S, Dewitz M, et al. Charnley low-friction arthroplasty of the hip: twenty-year results with cement. J Arthroplasty 1994; 9: 229-34.
2. Wiklund I, Romanus B. A comparison of quality of life before and after arthroplasty in patients who had arthrosis of the hip joint. J Bone Joint Surg Am 1991; 73: 765-9.
3. Laupacis A, Bourne R, Rorabeck C, et al. The effect of elective total hip replacement on health-related quality of life. J Bone Joint Surg Am 1993; 75: 1619-26.
4. Daly PJ, Morrey BF. Operative correction of an unstable total hip arthroplasty. J Bone Joint Surg Am 1992; 74: 1334-43.
5. McCollum DE, Gray WJ. Dislocation after total hip arthroplasty: causes and prevention. Clin Orthop Relat Res 1990; 261: 159-70.
6. O'Brien S, Engela D, Leonard S, Beverland D, Kernohan G. A study of the factors in hip replacement dislocation: part 2. Nurs Stand 1996; 11: 39-42.
7. Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am 1978; 60: 217-20.
8. D'Lima DD, Urquhart AG, Buehler KO, Walker RH, Colwell CW Jr. 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 2000; 82: 315-21.
9. Kummer FJ, Shah S, Iyer S, DiCesare PE. The effect of acetabular cup orientations on limiting hip rotation. J Arthroplasty 1999; 14: 509-13.
10. Bader R, Willmann G. [Ceramic cups for hip endoprostheses: Part 6: cup design, inclination and antetorsion angle modify range of motion and impingement] [article in German]. Biomed Tech (Berl) 1999; 44: 212-9.
11. Bader R, Willmann G. [Ceramic acetabular cups for hip endoprostheses: Part 7: how do position of the center of rotation and the CCD angle of the shaft modify range of motion and impingement?] [article in German]. Biomed Tech (Berl) 1999; 44: 345-51.
12. Kurtz SM, Edidin AA, Bartel DL. The role of backside polishing, cup angle, and polyethylene thickness on the contact stresses in metal-backed acetabular components. J Biomech 1997; 30: 639-42.
13. Chen FS, Di Cesare PE, Kale AA, et al. Results of cemented metal-backed acetabular components: a 10-year-average follow-up study. J Arthroplasty 1998; 13: 867-73.

14. Schmalzried TP, Guttmann D, Grecula M, Amstutz HC. The relationship between the design, position, and articular wear of acetabular components inserted without cement and the development of pelvic osteolysis. J Bone Joint Surg Am 1994; 76: 677-88.
15. McBroom R, Muller M. Aseptic loosening: fifteen years experience with the Muller total hip arthroplasty. Proceedings of the 39th Canadian Orthopeadic Association Meeting, Québec, 1983. J Bone Joint Surg Br 1984; 66: 300.
16. Kennedy JG, Rogers WB, Soffe KE, Sullivan RJ, Griffen DG, Sheehan LJ. Effect of acetabular component orientation on recurrent dislocation, pelvic osteolysis, polyethylene wear, and component migration. J Arthroplasty 1998; 13: 530-4.
17. Kummer FJ, Stuchin SA, Frankel VH. Analysis of removed autophor ceramic-on-ceramic components. J Arthroplasty 1990; 5: 28-33.
18. Dorlot JM, Christel P, Meunier A. Wear analysis of retrieved alumina heads and sockets of hip prostheses. J Biomed Mater Res 1989; 23 (suppl A3): 299-310.
19. Dowling JM, Atkinson JR, Dowson D, Charnley J. The characteristics of acetabular cups worn in the human body. J Bone Joint Surg Br 1978; 60: 375-82.
20. Boutin P, Christel P, Dorlot JM, et al. The use of dense alumina-alumina ceramic combination in total hip replacement. J Biomed Mater Res 1988; 22: 1203-32.
21. Maistrelli G, Gerundini M, Bombelli R. The inclination of the weight bearing surface in the hip joint: the clinical significance of abnormal force. Orthop Rev 1986; 15: 271-9.
22. Salvati EA, Im VC, Aglietti P, Wilson PD Jr. Radiology of total hip replacements. Clin Orthop Relat Res 1976; 121: 74-82.
23. Sedel L. Ceramic hips. J Bone Joint Surg Br 1992; 74: 331-2.
24. Sedel L, Kerboull L, Christel P, Meunier A, Witvoet J. Alumina-on-alumina hip replacement: results and survivorship in young patients. J Bone Joint Surg Br 1990; 72: 658-63.
25. Seki M, Yuasa N, Ohkuni K. Analysis of optimal range of socket orientations in total hip arthroplasty with use of computer-aided design simulation. J Orthop Res 1998; 16: 513-7.
26. Harkess W. Campbell's operative orthopaedics: arthroplasty of the hip. St Louis: Mosby 1998; 535.
27. Imura S. Biomechanics of total hip arthroplasty. East Jpn J Clin Orthop 1995; 7: 609-15.
28. Hassan DM, Johnston GH, Dust WN, Watson G, Dolovich AT. Accuracy of intraoperative assessment of acetabular prosthesis placement. J Arthroplasty 1998; 13: 80-4.
29. Digioia AM 3rd, Jaramaz B, Plakseychuk AY, et al. Comparison of a mechanical acetabular alignment guide with computer placement of the socket. J Arthroplasty 2002; 17: 359-64.
30. Vendittoli PA, Duval N, Stitson DJ, Masse B. Vertical acetabular positioning with an inclinometer in total hip arthroplasty. J Arthroplasty 2002; 17: 936-41.
31. Herrlin K, Pettersson H, Selvik G. Comparison of two- and three-dimensional methods for assessment of orientation of the total hip prosthesis. Acta Radiol 1988; 29: 357-61.
32. Seller R, Lyles D, Dorr L. The effect of pelvic on alpha and theta angles in total hip arthroplasty. Contemp Orthop 1988; 17: 67-70.
33. SAS. 8.2 ed. Cary, NC (USA): SAS Institute. [AUTHORS: please complete and clarify this reference: what is the TITLE and YEAR of publication for this reference? Is this a software (version 8.2)? or a published reference (8.2 ed.)?]
34. Sharp I. Acetabular dysplasia: the acetabular angle. J Bone Joint Surg Br 1961; 43: 268-72.
35. Moran KM, Ness K, Finkbeiner AA. Visual estimation of angles by orthopedic surgeons. Am J Orthop 2000; 29: 361-2 (discussion 363).
36. Pollard JA, Daum WJ, Uchida T. Can simple radiographs be predictive of total hip dislocation? J Arthroplasty 1995; 10: 800-4.
37. Pettersson H, Gentz CF, Lindberg HO, Carlsson AS. Radiologic evaluation of the position of the acetabular component of the total hip prosthesis. Acta Radiol Diagn (Stockh) 1982; 23 (3A): 259-63.
38. Del Schutte H Jr, Lipman AJ, Bannar SM, Livermore JT, Ilstrup D, Morrey BF. Effects of acetabular abduction on cup wear rates in total hip arthroplasty. J Arthroplasty 1998; 13: 621-6.
39. Nizard RS, Sedel L, Christel P, Meunier A, Soudry M, Witvoet J. Ten-year survivorship of cemented ceramic-ceramic total hip prosthesis. Clin Orthop Relat Res 1992; 282: 53-63.