Int J Clin Exp Med 2015;8(1):181-187
www.ijcem.com /ISSN:1940-5901/IJCEM0003071

Original Article

Using acetabular fossa as a guide for anticipated inclination of uncemented cup in total hip replacement

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Received October 10, 2014; Accepted January 5, 2015; Epub January 15, 2015; Published January 30, 2015

Abstract: Positions of acetabular implant generally are considered to be major causative factors of dislocation. Accurate and consistent achievement of the preoperatively anticipated orientation of the acetabular cup is a great challenge in total hip replacement (THR). In the present study, we investigated the surgical application of acetabular fossa as a guide for anticipated inclination of uncemented cup, and evaluated its accuracy as an anatomic reference for achieving the preoperatively anticipated abduction of the acetabular cup in comparison with traditional device method on cadaveric specimens. Sixteen normal adult pelvic cadaveric specimens were collected. On each of the sixteen normal adult pelvic cadaveric specimens, acetabular fossa related anatomic sites were marked and studied on pelvic radiographs. Our results showed that there is close correlation between most medial aspect of acetabular sourcil and central axis of the acetabular cup at anticipated inclination of 40° ± 5°. And the fossa group can achieve the preoperatively anticipated cup abduction more accurately than the device group. The current results demonstrated that acetabular fossa can be a reasonable alternative, or as a complement to the currently used methods guiding total hip replacement.

Keywords: Acetabular fossa, total hip replacement, radiographic characteristics, accuracy, anatomic reference, preoperative assessment

Introduction

Postoperative dislocation remains a major complication after total hip replacement (THR), with recent reports indicating an incidence of 0.6% to 5% [1]. Positions of acetabular implant generally are considered to be major causative factors of dislocation [2-4]. Proper orientation of an acetabular implant can be obtained by careful consideration of abduction and version angles. Most manufacturers recommend placement of the acetabulum within a so-called safe zone. This safe zone is based upon studies showing that the optimal radiographic orientation of the acetabulum is an abduction angle of 40° ± 10° and an anteversion angle of 15° ± 10° [5, 6]. Recently, abduction of 40° ± 5° has been advocated by most hip surgeons as the optimal inclination of the acetabular cup [6-9]. Abduction of the acetabular cup was also identified as being closely associated with prosthetic wear, which was the great concern for the long-term survival of THR [7-9].

Accurate and consistent achievement of the preoperatively anticipated orientation of the acetabular cup is a great challenge in THR, this is especially true for abduction of 40° ± 5° to be the desired goal [6, 10]. Commonly used methods for cup implantation include freehand technique, acetabular device assistance and anatomic landmarks [11-16]. However, the former two methods were greatly affected by intraoperative change of patient positioning, surgeon's experience, and/or inherent design limitation of the acetabular device, which may result in much deviation of the cup position from the anticipated values. Moreover, these techniques of measurement are subject to numerous problems including inaccuracies based on the variability of the patient's pelvic position on the operating table and difficulty in

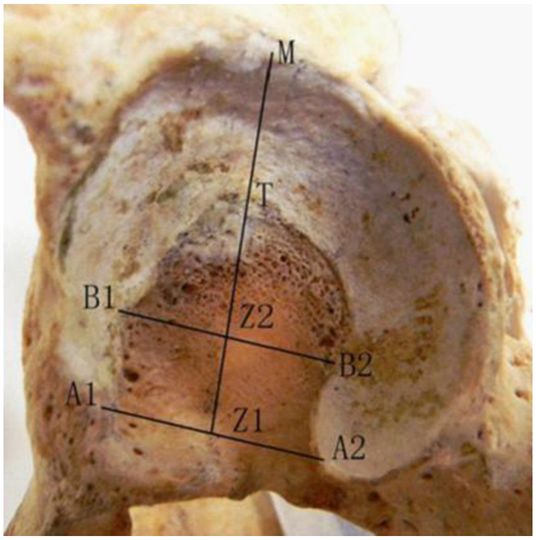

Figure 1. Central axis of the acetabular fossa (Z1Z2) extended through the top of fossa (at point T) and rim at point M. Z1 and Z2 were the midway of lineA1A2 and line B1B2 respectively.

Figure 2. Markers were placed at T, M, and T1 which was near to T and at the edge of the fossa.

application of preoperative templating to intraoperative decisions on radiographic landmarks [11, 17, 18]. The currently used landmarks, including acetabular notch angle, acetabular rim, and transverse acetabular ligament, have disadvantages such as false localization or necessitating extensive exposure [6, 14-16]. Computers have been suggested as an alternative combining preoperative radiographic data to intraoperative component orientation. DiGioia et al used computed tomographic (CT) scans and computerized component guidance

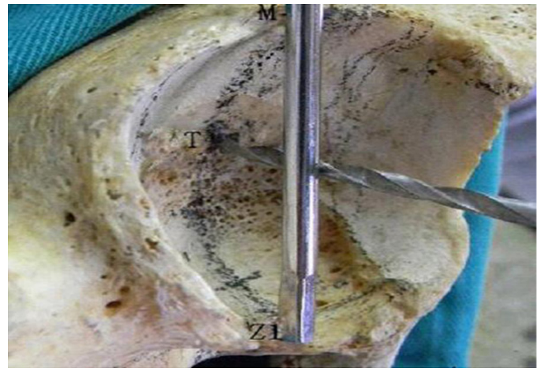

Figure 3. A hole was Drilled in the direction from midway of MZ1 toward point T, which was along the imaginary central axis of the cup.

to minimize dislocation in a small group of patients [19]. Although this technique demonstrates promise, the high financial costs and limited availability restricts the usefulness in routine daily application in all centers performing hip arthroplasty [16].

The anatomical characteristics of the acetabular fossa are stable. Moreover, it is easy to be identified in the normal acetabulum with limited exposure [20]. As far as we know, its role as an intraoperative reference for THR has not been investigated. The purpose of this work is to describe the surgical application of acetabular fossa, and to determine its accuracy as an anatomic reference for achieving the preoperatively anticipated abduction of the acetabular cup in comparison with traditional device method on cadaveric specimens.

Laboratory investigations were undertaken to prove the efficacy of these landmarks in placement of acetabular components. The laboratory investigation used in vitro measurement to establish a relationship between the native anatomical orientation of the acetabulum and of the acetabular fossa.

Materials and methods

Between May 1997 and February 2001, sixteen normal adult pelvic cadaveric specimens were collected. All the specimens were provided by Anatomic Department of Medical College of Zhengzhou University and were donated from volunteers. There were ten males and six females. Devices needed included metal markers (lead wire), specialized immobilization device for pelvic specimens, the acetabular

Figure 4. Acetabular reaming was performed concentrically along the hole-drilling direction with the diameter of the reamer in line with the central axis of the acetabular fossa.

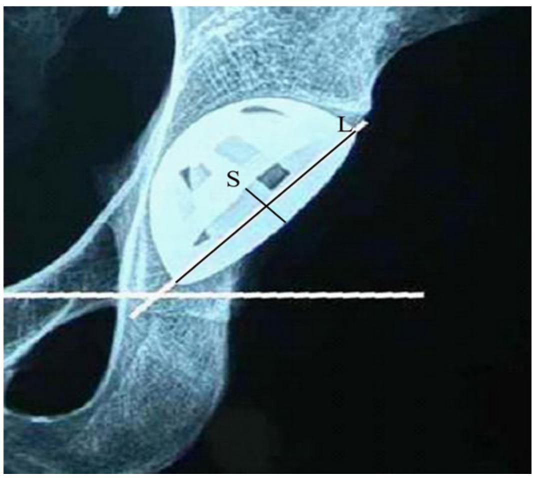

Figure 5. On anteroposterior pelvic film, abduction angle was determined by the intersection of long axis of cup and inter-teardrop line.

reamers and power, the acetabulum cup trials, Kirschner wire, drill (diameter 3 mm) and power.

First, radiographic characteristics of the acetabular fossa related anatomy and its correlation with the anticipated cup abduction on preoperative templating were investigated. The central axis of acetabular fossa was determined as followed (**Figure 1**). A1 and A2 were the two points equivalent to the insertions of the acetabular transverse ligament. Z1 was the midpoint of line A1A2. Line B1B2 was parallel with A1A2 and intersected with the anterior and posterior edge of the fossa at B1 and B2, respectively. Z2 was the midpoint of line B1B2. The line that connected Z1 and Z2 was the central axis of acetabular fossa. The Z1Z2 line intersected the curved top of the fossa and the acetabular osseous rim at point T and point M respectively. Point T and point M were marked

Figure 6. Markers at T and M correspond to most medial and lateral aspect of acetabular sourcil respectively, with T1 being away from the sourcil.

using metal markers. Point T1 was marked as a non-T point and was used as control (**Figure 2**). Standard anteroposterior pelvic X-ray was taken as recommended by previous study [21]. The radiographic projection of point T and point M on the standard anteroposterior pelvic X-ray film was observed. Preoperative templating was performed on the standard anteroposterior pelvic X-ray films. The goal of acetabular cup placement met the following criteria: the inferomedial corner should be at the interteardrop level; the innermost edge should not pass over the iliopubic line; the top should contact the subchondral bone; the superior-lateral cup should not be excessively uncovered [22, 23]. Based on the above templating technique, a line perpendicular to the acetabular cup diameter through the center of the acetabular cup was made with the cup at 45° acetabular abduction. The central axis of the acetabular cup was actually equal to the anticipated direction of acetabular reaming, which intersected with medial wall at R1. Similarly, the central axis of cup placed at 35° abduction was determined, which intersected with medial wall at R2. The relationships between R1, R2 and point R (R was the radiographic projection of point T) were observed. When the central axis of acetabular cup passed through the point R, the anticipated abduction was measured.

Then, the accuracy of using fossa as reference was evaluated. Acetabular cup implantation was performed on both sides of the acetabulum. On one side, acetabular fossa was used as reference for cup implantation, while on the other side the traditional acetabular device method was applied as a control. On the fossa reference side, pelvic specimens were fixed in standard lateral position, and were draped with only the acetabulum being exposed. With 40°

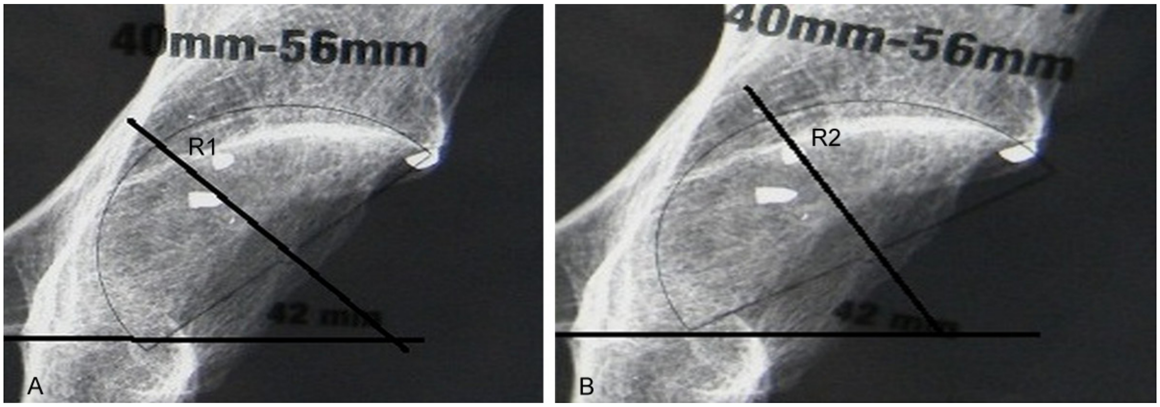

Figure 7. With templating, central axis of cup intersected with medial wall at R1 when the inclinaton angle is 45° (A). With templating, central axis of cup intersected with medial wall at R2 when the inclinaton angle is 35° (B). R lies between R1 and R2.

Table 1. Difference of cup abduction before and after surgery and post-anteversion between groups

Groups	Postoperative abduction	Difference of Pre- and Post-operaton abduction	Postoperative Anteversion
Fossa Group	40.19° ± 3.15° (34°~45°)	0.19° ± 3.14° (-6°~5°)	20.44° ± 2.63° (15°-25°)
device Group	42.13° ± 3.40° (36°-48°)	2.75° ± 2.89° (-2°-8°)	21.81° ± 4.12° (15°-30°)
Statistics	t = -2.087, P = 0.054	t = -2.453, P = 0.027	t = -1.915, P = 0.075

acetabular abduction as the goal for implantation, the relationship between the anticipated central axis of the cup and the most medial point of acetabular sourcil (point R, equivalent to T-point on specimens) was determined on preoperative templating. Their relationship is such that the central axis through point R in 11 cases, about 1 mm medial to R in 3 cases, and about 1 mm lateral to R in 2 cases. On the basis of this measurement and prior to acetabular reaming, the point T was marked by drilling a hole in 3 mm in diameter and 5 mm in depth. The drill was directed along the imaginary central axis of the cup. This direction was practically determined by the line through the midpoint of MZ1 and T point (or 1 mm medial or lateral to it based on measurement) (**Figure 3**). The acetabulum reaming was performed in the reaming center, and the maximum diameter of the reamer was in line with MZ1 (**Figure 4**). Concentrically, reaming was kept throughout the procedure until the appropriate cup size was reached. The acetabular trial in the final size was placed as follows: the center of the bottom hole of the cup must coincide with the drilling center, and its diameter in line with MZ1, the lower edge should not exceed the point Z1. The superior-lateral part of the cup was usually undercovered by no more than 5 mm. Then, this desired position was marked by drawing a line along the anterior rim of the trial on the anterior wall, which was helpful for the subsequent implantation to ensure that the position of acetabular cup is consistent with the expected position. For the control group, acetabular reaming was performed on the basis of surgeon' experience and acetabular device was used for final cup placement in accordance with the corresponding procedural instructions.

After implantation, standard anteroposterior pelvic X-ray film was taken. The long axis (L) and short axis (S) of the ellipse were depicted (**Figure 5**). Abduction of the cup was measured as the angle between the long axis of ellipse and the inter-teardrop line. Anteversion of the cup was calculated as β = arc sin (the S/L) according to the Pettersson formula [24]. Each X-ray film was measured by two orthopedic surgeons respectively, and repeated one week later. The average of the measurements was taken as the final value.

Statistical analyses

All data were presented as mean ± standard error. The difference of abduction before and after operation for fossa reference group was compared with that of device group using the paired Student's *t*-test. Statistical analysis was performed with SPSS software (Version 13.0; SPSS Inc, Chicago, IL), and statistical significance was set at $P < 0.05$.

Results

It was interesting that acetabular fossa intimately correlated with acetabular sourcil, which closely correlated with desired abduction angle between 35° and 45°. The central axis approximately divided the fossa equally, which intersected with the top of fossa at point T and with acetabular bony rim at M. On standard anteroposterior pelvic films, the metal marker located at point T always corresponded to the most medial aspect of acetabular sourcil (point R), and the metal marker at point M constantly corresponded to the most lateral aspect of acetabular sourcil (**Figure 6**). R points were constantly located between point R1 and R2 (**Figure 7A**, **7B**). When the central axis of cup passed through the most medial aspect of acetabular sourcil , the abduction averaged 40.66° ± 2.44°, which was close to 40°. This suggested that central axis passed through the most medial aspect of acetabular sourcil (point R) should have an abduction angle between 35° and 45°.

Statistically significant difference in discrepancy between preoperatively predicted abduction and actually postoperative value was found between fossa reference group and device group (**Table 1**), although the difference of postoperative cup abduction between the two groups was not statistically significant (**Table 1**). In fossa group, one hip's abduction was 34°, and the remaining 15 hips were in the range of 40° ± 5°, whereas in device group, 3 hips' abductions were more than 45°, The remaining 13 hips had abduction in the range of 40° ± 5°.

Another interesting finding was the anteversion angle in the fossa group. The anteversion in the fossa group was all within the desired safe range (20° ± 5°) with its distribution close to 20°. While among the device group, the anteversion values were not so closely distributed and three cases had abduction greater than 25°. Because the preoperative anteversion cannot be predicted by templating measurement, deviation between preoperative and postoperative anteversion was not calculated. When postoperative anteversion were compared between the two groups, the difference between was not statistically significant (**Table 1**). These results showed that the fossa reference method can also accomplish reasonable anteversion of the acetabular cup.

Discussion

In THR, cup position is considered to be important factors in risk of postoperative dislocation. Accurate and reproducible measurement of cup position is crucial for evaluation of the importance of component positions and estimation of the risk of dislocation. Conventional methods cannot consistently provide accurate measurement, in spite of developments in processing techniques. Also, it is often difficult to locate the elliptical opening of the cup for calculation of anteversion from radiographs, especially when the cup is metal backed. Due to excellent stability, the acetabular fossa is a relative ideal anatomic landmark candidate [20]. With the unique anatomy of individual acetabular fossa, it may potentially have biomechanical advantage in serving as a reference for cup implantation. Furthermore, acetabular sourcil is a constant radiographic finding on anteroposterior pelvic radiograph, so it is practically helpful to use it as reference for preoperative templating measurement. However, its role as an intraoperative reference for cup implantation has not been systemically investigated, as well as its radiographic characteristics of normal acetabular fossa on standard pelvic film and its correlation with cup abduction of 40° ± 5° on templating measurement. In the current study, we demonstrated that intersection of central axis of acetabular fossa with fossa top edge and the most medial aspect of acetabular sourcil correlates closely with the central axis of the acetabular cup at anticipated abduction of 40° ± 5°.

Our results showed that the fossa referencing technique not only has greater accuracy in achieving the preoperatively anticipated cup abduction compared with control group, but also has great consistency in obtaining reasonable anteversion. These results were comparable to that of computer navigation technology. Sotereanos and co-workers reported a technique using intraoperative pelvic landmarks for acetabular component placement in THR. In a series of 26 THR hips using the computer navigation system, higher consistency of postoperative cup orientation with preoperatively anticipated inclination and anteversion was reported. With the preoperative goal of abduction and anteversion as 40° and 30°, respectively, postoperative abduction and anteversion were optimized as 39.4° ± 4.0° and 32.6° ± 7.0° respectively [16, 25]. What is more, the fossa reference technique was relatively easier to perform without special equipment. Also, the index technique had advantages over other reported anatomic reference techniques. A study using osseous landmarks including the lowest point of the acetabular sulcus of the ischium as reference for acetabular cup implantation demonstrated as high as 96% rate of consistency of postoperative inclination with preoperative predicted values. However, the preoperatively anticipated range of abduction was relatively wider (40° ± 10°), and the postoperative range of inclination achieved was also wider with a relatively higher mean angle of 44.4° (24°-58°). In addition, there was need for more extensive exposure and difficulty with localization of the described anatomical landmarks during operation [16]. In recent years, it has been reported that the transverse acetabular ligament (TAL) could be applied as reference to guide intraoperative cup implantation and reported lower dislocation rate (6/1000). Whereas, this method failed to accurately determine abduction angle. And there was no specific data about the postoperative abduction and anteversion [14]. Furthermore, the feasibility and accuracy of the TAL reference method was controversial because TAL can only be identified in about 47% patients who underwent primary THR. Also, this study failed to find the advantages of TAL reference technique over acetabular device method in terms of accuracy in cup implantation [15].

In this study, drilling a hole at the point T (around which reaming was performed) in the direction of the expected central axis of acetabular cup virtually guarantees that the vertex always can be identified. The bone defect created is very mild and can be filled with local bone if necessary. The process of acetabular cup implantation may be affected by a variety of factors, which may compromise the consistency of the final position of cup with the reaming direction and the trial position [17]. For this purpose, in addition to the drilling hole method in the current study, marking the trial position by drawing parallel line with the trial rim on the anterior wall of the acetabulum is reasonable. Of course, how to ensure that the final position of acetabular prosthesis should be consistent with the anticipated trial position needs further investigation.

In conclusion, with carefully preoperative templating, the relationship between the desired inclined cup and lateral aspect of acetabular sourcil can be precisely determined, which implied that the anticipated acetabular cup can be accurately obtained if the preoperative measurement was duplicated with the current technique. Meanwhile, appropriate cup anteversion can also be achieved using this technique. This method was not influenced intraoperatively by the change of patient position, and had advantages over other commonly used anatomic landmarks in its greater accuracy, reproducibility, easier to perform and no need for extensive exposure. In primary THR with relative normal anatomy of acetabulum, this method has great value in obtaining the desired orientation of acetabular cup. Of course, combination with other methods available would add further accuracy.

Acknowledgements

Our paper was supported by the First Affiliated Hospital of Zhengzhou University, 2009-WQN-004.

Disclosure of conflict of interest

None.

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References

[1] Nishii T, Sugano N, Miki H, Koyama T, Takao M, Yoshikawa H. Influence of component positions on dislocation: computed tomographic evaluations in a consecutive series of total hip arthroplasty. J Arthroplasty 2004; 19: 162.

[2] Dorr LD, Wolf AW, Chandler R, Conaty JP. Classification and treatment of dislocations of total hip arthroplasty. Clin Orthop 1983; 173: 151.

[3] McCollum DE, Gray WJ. Dislocation after total hip arthroplasty. Clin Orthop 1990; 261: 159.

[4] Robinson RP, Simonian PT, Gradisar IM, Ching RP. Joint motion and surface contact area related to component position in total hip arthroplasty. J Bone Joint Surg Br 1997; 79: 140.
[5] Herrlin K, Selvik G, Pettersson H, Kesek P, Onnerfält R, Ohlin A. Position, orientation and component interaction in dislocation of the total hip prosthesis. Acta Radiol 1988; 29: 441.
[6] Moskal JT, Capps SG. Improving the accuracy of acetabular component orientation: avoiding malposition. J Am Acad Orthop Surg 2010; 18: 286.
[7] Leslie IJ, Williams S, Isaac G, Ingham E, Fisher J. High cup angle and microseparation increase the wear of hip surface replacements. Clin Orthop Relat Res 2009; 467: 2259.
[8] Little NJ, Busch CA, Gallagher JA, Rorabeck CH, Bourne RB. Acetabular polyethylene wear and acetabular inclination and femoral offset. Clin Orthop Relat Res 2009; 467: 2895.
[9] Wan Z, Boutary M, Dorr LD. The Influence of Acetabular Component Position on wear in total hip arthroplasty. J Arthroplasty 2008; 23: 51.
[10] Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip replacement arthroplasties. J Bone Joint Surg Am 1978; 60: 217.
[11] Bosker BH, Verheyen CC, Horstmann WG, Tulp NJ. Poor accuracy of freehand cup positioning during total hip arthroplasty. Arch Orthop Trauma Surg 2007; 127: 375.
[12] Jolles BM, Genoud P, Hoffmeyer P. Computer-assisted cup placement techniques in total hip arthroplasty improve accuracy of placement. Clin Orthop Relat Res 2004; 426: 174.
[13] Padgett DE, Hendrix SL, Mologne TS, Peterson DA, Holley KA. Effectiveness of an acetabular positioning device in primary total hip arthroplasty. HSSJ 2005; 1: 64.
[14] Archbold HA, Mockford B, Molloy D, McConway J, Ogonda L, Beverland D. The transverse acetabular ligament: An aid to orientation of the acetabular component during primary total hip replacement. A preliminary study of 1000 cases investigating postoperative stability. J Bone Joint Surg Br 2006; 88: 883.
[15] Epstein NJ, Woolson ST, Giori NJ. Acetabular component positioning using the transverse acetabular ligament: can you find it and does it help? Clin Orthop Relat Res 2010; 429: 412.
[16] Sotereanos NG, Miller MC, Smith B, Hube R, Sewecke JJ, Wohlrab D. Using intraoperative pelvic landmarks for acetabular component placement in total hip arthroplasty. J Arthroplasty 2006; 21: 832.
[17] Beckmann J, Lüring C, Tingart M, Anders S, Grifka J, Köck FX. Cup positioning in THA: current status and pitfalls. Arch Orthop Trauma Surg 2009; 129: 863.
[18] Minoda Y, Ohzono K, Aihara M, Umeda N, Tomita M, Hayakawa K. Are acetabular component alignment guides for total hip arthroplasty accurate? J Arthroplasty 2010; 25: 986.
[19] DiGioia AM, Jaramaz B, Blackwell M, Simon DA, Morgan F, Moody JE, Nikou C, Colgan BD, Aston CA, Labarca RS, Kischell E, Kanade T. The Otto Aufranc Award. Image guided navigation system to measure intraoperatively acetabular implant alignment. Clin Orthop 1998; 355: 8.
[20] Govsa F, Ozer MA, Ozgur Z. Morphologic features of the acetabulum. Arch Orthop Trauma Surg 2005; 125: 453.
[21] Clohisy JC, Carlisle JC, Beaulé PE, Kim YJ, Trousdale RT, Sierra RJ, Leunig M, Schoenecker PL, Millis MB. A Systematic approach to the plain radiographic evaluation of the young adult hip. J Bone Joint Surg Am 2008; 90 Suppl 4: 47.
[22] Clark CR, Huddleston HD, Schoch EP 3rd, Thomas BJ. Leg-length discrepancy after total hip arthroplasty. J Am Acad Orthop Surg 2006; 14: 38.
[23] Gamble P, de Beer J, Petruccelli D, Winemaker M. The accuracy of digital templating in uncemented total hip arthroplasty. J Arthroplasty 2010; 25: 529.
[24] Haenle M, Mittelmeier W, Barbano R, Wörtler K, Scholz R, Bader R. Accuracy and reliablity of different methods to evaluate the acetabular cup version from plain radiographs. Surg Radiol Anat 2010; 32: 725.
[25] Ryan JA, Jamali AA, Bargar WL. Accuary of computer navigation for acetabular componnent placement in THA. Clin Orthop Relat Res 2010; 468: 169.