Institute of Medical & Biological Engineering

# The Determination of Three-dimensional Acetabular Orientation in Different Coordinate Systems

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## Background

- Mal-positioning of the acetabular component in total hip replacement (THR) could lead to unexpected complications such as edge loading, accelerated component wear, impingement and dislocation [1,2].
- The orientation of acetabulum/acetabular component was usually determined relative to the pelvic coordinate system in previous studies [3].
- The functional acetabular orientation should be determined in a global body coordinate system considering the tilt of pelvis relative to the human body.
- The aims of the study were to establish a pelvic coordinate system and a global body coordinate system, and to assess the acetabular orientations of natural hip in different coordinate systems form a large cohort of subjects.

## Materials and Methods

- Three-dimensional (3D) computed tomographic (CT) images of 56 subjects (28 males and 28 females) in supine position were obtained.
- 3D solid models of pelvis and spine were generated from the CT images.
- The acetabular orientations and coordinate systems were determined using a custom-written MATLAB program.

***Pelvic coordinate system***

- Four bony landmarks on the pelvis, the right and left anterior superior iliac spines (RASIS and LASIS), the right and left pubic tubercles (RPT and LPT) were determined (Fig. 1a and 1b).
- The coordinate system was established based on the bony landmarks (Fig.1c).

***Global body coordinate system***

- The bony landmarks on the spine including the geometric centers of five lumbar vertebrae bodies (L1, L2, L3, L4, L5), the most dorsal points on the five corresponding spinous processes (S1, S2, S3, S4, S5) and the anterior sacral promontory were determined (Fig. 2a and 2b).
- The coordinate system was created based on the landmarks (Fig. 2c).

***Acetabular rim plane***

- A set of points along the acetabular rim were determined (Fig. 3a and 3b).
- The points were fitted to a plane using least squares method (Fig. 3c).
- The acetabular orientation was characterized using three components (x-,y-,z-) of the unit normal vector of the acetabular rim plane in the coordinate system.

## Materials and Methods

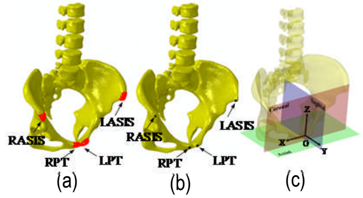


*Fig. 1 (a) point clouds around the bony landmarks were captured, (b) the four bony landmarks were determined based on the point clouds using a custom-written MATLAB program, (c) the pelvic coordinate system was created using the four bony landmarks.*

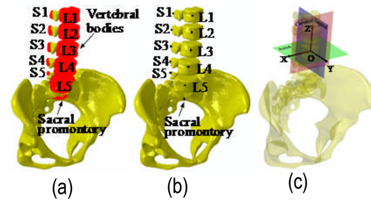


*Fig. 2 (a) point clouds around the bony landmarks on the lumbar spine were captured, (b) the bony landmarks were determined using the MATLAB program, (c) The global body coordinate system was established using the determined bony landmarks.*

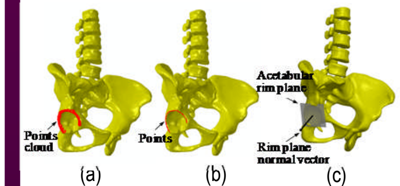


*Fig. 3 (a) point clouds around the acetabular rim, (b) a set of points were determined based on the point clouds, (c) the acetabular rim plane and its corresponding unit normal vector.*

## Results

- The scatter plots and magnitudes of the three components (x-, y-, z-) of the unit normal vector for the acetabular rim plane in the two coordinate systems are shown in Fig. 4 and Table 1.
- Statistically significant differences of y- and z- components of the unit normal vector were observed between the measurements in the two coordinate systems (p<0.05).
- No difference of x- component were found (p=0.22). The best-fit line of x- components for the measurements in the two coordinate systems was not statistically different from the line y=x (pelvic measurement=global body measurement) ($R^2$=0.69, p<0.05).

## Results

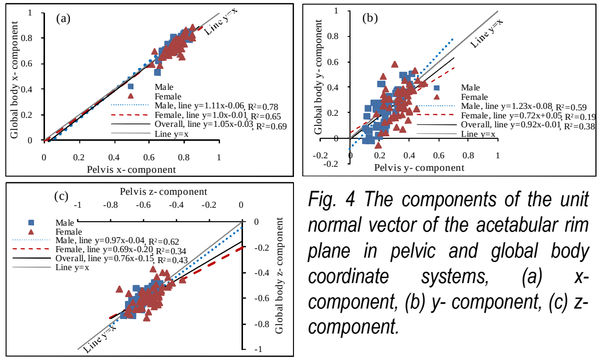


*Fig. 4 The components of the unit normal vector of the acetabular rim plane in pelvic and global body coordinate systems, (a) x-component, (b) y- component, (c) z-component.*

| Components | Coordinate systems | | Significant difference (p value) |
|---|---|---|---|
| | Pelvis measurements | Global body measurements | |
| x - | 0.75±0.05 (0.61 – 0.85) | 0.74±0.06 (0.53 – 0.89) | P=0.22 |
| y - | 0.30±0.09 (0.11 – 0.50) | 0.26±0.13 (-0.05 – 0.58) | P<0.01 |
| z - | -0.58±0.07 (-0.75 - -0.37) | -0.59±0.08 (-0.75 - -0.37) | P<0.05 |

*Table 1. The x-, y- and z- components of the unit normal vector of the acetabular rim plane in pelvic and global body coordinate systems.*

## Discussion

- Different variations of acetabular orientations in natural hip were measured in the two coordinate systems.
- There were larger variations of acetabular orientations in the global body coordinate system compared to those in the pelvic coordinate system.
- The different variations of the acetabular orientation relative to the two coordinate systems were mainly attributed to the tilt of the pelvis relative to the human body in the sagittal plane.
- It is suggested that a global body coordinate system considering the tilt of pelvis is necessarily required to define the acetabular orientation in order to achieve a correct positioning of THR component in clinical practice.

**References**
[1] Fisher J. J Bone Joint Surg Br. 2011.
[2] Brown TD et al. Iowa Orthop J. 2014.
[3] Austin MS et al. Clin Orthop Relat Res. 2009.
[4] Ferguson AB. Radiology. 1933.

**Acknowledgements**
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