VARIATION OF ACETABULAR CUP ORIENTATION DUE TO SOFT-TISSUE OVERLAYING BONY LANDMARKS IN TOTAL HIP ARTHROPLASTY (THA) USING IMAGELESS COMPUTER ASSISTANT NAVIGATION SYSTEM

INTRODUCTION: The utilization of an imageless Computer-Assisted Navigation System (iCNS) in THA has been shown to be an effective tool for the intraoperative optimum alignment of the acetabular cup [1-2]. Precise placement of the cup depends on an accurately defined Anterior Frontal Pelvic Plane (AFPP). However, in obese individuals, who account for more than half of the patient population [3], the AFPP can be sometimes deviated from the real location due to the difficulty in palpating the bony landmarks through the substantial amount of the soft tissue. This difficulty in identifying the bony landmarks may increase the possibility of misalignment of the hip prostheses, resulting in the failure of THA [4]. The objective of this study was, therefore, to evaluate possible error in the acetabular cup alignment (orientation) induced by variations in the AFPP resulting from mal-palpating bony landmarks due to the soft tissue overlaying pelvis landmarks in THA using iCNS.

MATERIALS AND METHODS

Participant, Surgery, and CT Examination: Human subjects were included after obtaining informed consent approved by the Institutional Review Board. THA was performed on a total of 50 hips for human subjects (46 patients: 26 female and 20 male; 63.3±12.4yrs, 173.9±12.0cm, and 84.6±11.8kg) with or without the aid of iCNS (Stryker® Navigation System, Stryker Corporation, Kalamazoo, MI). The targeted acetabular cup orientation was 40-45° for inclination and 17-23° for anteversion. CT scans for all individuals were obtained postoperatively in the supine position with the following parameters: 1.25mm thickness, 140Kv, 270mA, and 1.0 scan time.

Determination of Acetabular Cup Orientation: A 3-D model of the pelvis together with the prosthesis was created for each hip from the CT scans (hereafter, the CT3D model) using Mimics software (Materialise Software, Ann Arbor, MI, USA). Anatomical landmarks were then identified on the bilateral Anterior Superior Iliac Spines (ASISs) and the Pubic Symphysis (PS). Soft-tissue thickness along the anterior direction was measured from the CT image for each individual over the three bony landmarks. With this information, the bony landmarks in the CT3D model were shifted from the identified location in the anterior direction to simulate possible error in palpating the landmarks resulting from interference by soft tissue. The simulation was for the greatest error which might occur in the palpation of the bony landmarks due to the presence of the soft tissue.

Determination of AFPP: First, the orientation of the AFPP for the true bony structure was determined from the three bony landmarks without considering the soft-tissue. Here, the AFPP for the anatomical pelvic structure was named AFPPB. Second, an AFPP was determined based on the three shifted soft-tissue landmarks to simulate possible error resulting from the soft tissue when palpating the bony landmarks. This AFPP was named AFPPS. Data of AFPPB served as the true values.

Acetabular Cup Orientation: Multiple points (a minimum of 11) were selected along the prostatic acetabular rim to define the acetabular plane from the CT3D model. The acetabular plane was defined by fitting a plane to the digitized points on the prostatic acetabular rim using a least-square-error algorithm. The orientation of the acetabular cup was then determined using the relative orientation of this acetabular plane to the 2 AFPPB (AFPPB and AFPPS). These data of the acetabular cup orientations formed the groups of CT3D-AFPPB and CT3D-AFPPS, respectively. In addition, the acetabular cup orientations for 25 hips that received THA using iCNS were documented directly from the intraoperative palpation by the iCNS system. This was to identify practical error in THA with the aid of iCNS that resulted from interference of the soft tissue. These data were assigned to the group DIRECT-PAL.

Data Analyses: For each hip, the difference between the CT3D-AFPPB and the CT3D-AFPPS was calculated. This represented the deviation induced by the soft tissue. For each pelvis, a tissue thickness index was calculated as subtracting the average soft tissue thickness at bilateral ASISs from the soft tissue thickness at PS. This soft tissue index is a measure of how much the AFPP could be tilted away from its actual orientation determined by the true bony landmarks. A linear regression was performed to establish the linear relationship between the acetabular cup angle error (between the acetabular cup orientations relative to the AFPPB and AFPPS) and the tissue thickness index (Fig 1). A one-way ANOVA with Tukey's-sb post hoc test was used to identify significant differences among the tissue thickness indices in the groups of CT3D-AFPPB, CT3D-AFPPS, and DIRECT-PAL (Fig. 2). The level of significance was set at 0.05.

RESULTS: Fig. 1 shows the relationship between the acetabular cup angle error and the tissue thickness index for a total of 50 hips. The angle difference was increased generally with the increase of the tissue thickness index (R=0.80, p<0.001 for anteversion, R=0.64, p<0.001 for inclination). Fig. 2 shows the distribution of the acetabular cup orientation obtained from three different groups (CT3D-AFPPB, CT3D-AFPPS, and DIRECT-PAL) for a total of 25 hips that received iCNS aided THA. The average anteversion for CT3D-AFPPB, CT3D-AFPPS, and DIRECT-PAL were 26.7±6.0°, 13.1±2.0° and 21.5±2.3°, respectively. The average inclination computed from CT3D-AFPPB, CT3D-AFPPS, and DIRECT-PAL were 43.8±3.2°, 40.5±6.2° and 42.1±1.4°, respectively. The statistical results to identify a significant difference among the groups for the acetabular cup orientations (anteversion and inclination) were also shown in Fig. 2. The difference between the average acetabular cup orientations obtained from CT3D-AFPPB and DIRECT-PAL was an average of 5° for the anteversion and 1° for the inclination. It is not statistically significant; however, the clinical meaning of the 5° error in the anteversion should be further examined.

DISCUSSIONS AND CONCLUSIONS: This study is a first attempt to quantify a potential error in the acetabular cup orientation, caused by the interference of the soft tissue, and to simulate possible error resulting from the soft tissue when palpating the bony landmarks. This difficulty in identifying the bony landmarks may increase the possibility of misalignment of the hip prostheses, resulting in the failure of THA. The higher the soft tissue index, the higher the possible errors. In particular, the bony landmarks should be palpated carefully for patients who have a large amount of soft tissue on the PS. This may improve the acetabular cup alignment and consequently result in the reduction of premature failure and revision requirement of THA.


Acknowledgements: The authors are grateful for Materialise Software for supplying Mimics software; Fasanati, C. for CT image acquisition and support from Stryker Corp., Kalamazoo, Michigan.

Fig. 1. Acetabular cup orientation errors in relation to the soft-tissue thickness index. A linear regression was used to establish the linear relationship between the acetabular cup angle error and the tissue thickness index.

Fig. 2. Distribution of the acetabular cup anteversion (left) and inclination (right) obtained from the groups of CT3D-AFPPB (left, n=25), CT3D-AFPPS (right, n=25), and DIRECT-PAL (center, n=25). Asterisk indicates a significant difference with one-way ANOVA (p: significant level)