Vital Protocol for Reliability and Accuracy of PolyWare™ Measurements

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Research

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Abstract

Background: PolyWare™ software (PW) has been exclusively used in most of the polyethylene wear studies of total hip arthroplasty (THA). But, we found that PolyWare™ (PW) measurements can be significantly inaccurate and unrepeatable depending on imaging conditions or subjective manipulation choices. In this regard, this study reveals the required conditions to achieve the best accuracy and reliability of the PW measurements.

Methods: The experiment examined the dependency of PW on several measurement conditions. The X-ray images of in-vitro THA prostheses were acquired under a clinical X-ray scanning condition. A liner wear of 6.67 mm, an acetabular lateral inclination of 36.7° and an anteversion of 9.0° were simulated.

Results: Among all the imported X-ray images, those with a resolution of 1076×1076 exhibited the best standard deviation in wear measurements as small as 0.01 mm and the least occurrences of blurriness. The edge detection area specified as non-squared and off the femoral head center exhibited the most occurrence of blurriness. At the X-ray scanning moment, an eccentric placement of the femoral head center by 15 cm superior to the X-ray beam center led to an acetabular anteversion error up to 5.3°.

Conclusion: The results request researchers to observe following conditions; 1) the original Xray image be 1076×1076 squared X-ray images, 2) the edge detection area be specified as a square with edge lengths of 5 times the diameter of the femoral head centered at the femoral head center, 3) the femoral head center or acetabular center be placed as close to the center line of the X-ray beam as possible, at the X-ray scanning moment.

Full Text

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Figures

Figure 1

Error (in absolute value) in the wear for spatial eccentricity modes of the femoral head in the original X-ray images

Figure 2

Errors (in absolute value) in the acetabular anteversion for spatial eccentricity modes of the femoral head in the original X-ray images

Acetabular anteversion = $\sin^{-1}\left(\frac{l}{L}\right)$
by Lewinnek[12]

Acetabular anteversion = 3.6°

Acetabular anteversion = 0°

Acetabular anteversion = -2.7°

Figure 3

Measurement of acetabular anteversion using a CAD to investigate the effect eccentricity of the prosthesis from the center of X-ray beam on the acetabular anteversion. The same X-ray images used for Polyethylene measurements were also used for the measurement using a CAD software, i.e. Rapidform 2006®(INUSTechnology, Seoul, Korea). The superior and inferior placements of the prosthesis bring about errors in acetabular anteversion, by the nature of perspective X-ray imaging.

Figure 4

Overall process scheme of the current study

Figure 5

PolyWare work flow

Figure 6

X-ray images of the initial (the left) and final (the right) positions, simulating the wear of the cup by a translation of the femoral stem of 6.67 mm normal to the equator plane of AC.

Figure 7

Measured values for Ployware evaluation. (a) Wear X-ray images of the initial (the left) and final (the right) positions, simulating the wear of the cup by a translation of the femoral stem of 6.67 mm normal to the equator plane of AC.

Figure 8

Eccentricity comparison test setup, i.e. nine spatial eccentricity modes. With respect to the center of the X-ray detector, nine spatial eccentricity locations of the THA prostheses were set up to figure out how the eccentricity of the component location affected PolyWare measurement results.

Normal

Blurred

Figure 9

Blur of the edge detection area. For the same X-ray image, different specifications of rectangular edge detection areas result in different image sharpness. The left is shown normal, but the right is shown blurred. In the normal case, the rectangular edge detection area is specified such that its center positions at the very center of the femoral head. In the blurred case, in contrast, the rectangular edge detection area is specified such that its center positions considerably off the center of the femoral head, and the edge detection area becomes blurred.

Head-centered $5D_h \times 5D_h$ square

Head-centered $7D_h \times 7D_h$ square

Not head-centered non-square

Figure 10

Three ways of specification of the edge detection area. Edge detection area assigned as a rectangle whose edge lengths were 5 times ($5D_h$) square, 7 times ($7D_h$) square of the diameter of the femoral head

component (D_h), or non-square. The square areas specified were centered at the FH center, whereas non-square one off the FH center.