AUTOMATIC POLYETHYLENE WEAR MEASUREMENT OF METAL-BACKED HIP PROSTHESSES WITH THREE DIMENSIONAL COMPUTED TOMOGRAPHY

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Introduction:
Polyethylene wear measurement is important for evaluation of polyethylene liners. Previous reports of in-vivo wear measurement have been used x-ray films to estimate penetration of inner head. However, accuracy was not enough because of manual process and varying X-ray quality. Using extended scale computed tomography (CT) technique, we achieved clear image of both inner head and outer head. With the use of custom software, computer analysis of three dimensional (3D) data resulted in highly reproducible automatic wear measurement. The purpose of this study is to evaluate the accuracy and reproducibility of new method.

Methods:
Phantom study was performed to test the accuracy and reproducibility of the new method. 3D spiral CT techniques and computer program: 3D spiral CT (SOMATOM PLUS 4, SIEMENS, Germany) imaging was performed with 140kVp, 171mA and 0.75-second spiral-1mm slice with 1mm feed. Reconstruction interval was set to 0.5mm. Maximum window level was set to 30710HU (extended scale method). 512 × 512 pixel image data of CT was transported to the computer workstation and processed under custom software. Distribution of CT value was examined and the threshold level that can cut off metal artifact effectively is decided automatically. Only the metal objects are transported to the computer workstation and processed under custom software. Validation: Three graded artificially worn polyethylene liners (wear depth 0mm, 1mm and 3mm) were made by machine milling and mounted in 44mm and 54mm titanium acetabular cups (Trilogy Multihole cup), and 50mm CoCrMb outer head (Multipolar, Zimmer, Warsaw, IN.). 26mm or 22mm femoral heads were fit and fixed with the liners. Original 0mm wear liners were attached to 48mm and 52mm HGP2 cups (Zimmer, Warsaw, IN) with 22mm femoral head. CT measurements were performed with the phantom prostheses in water each for at least 6 times. After imaging, the liners were measured with a contact-scanner (MAX-HEIGHT HF-20, NSK Co. Japan) to know real wear. Calculated penetration were compared with real wear.

Results:
In all polyethylene liners, wear measurement were satisfactorily performed with new method. Average errors were within 0.5mm and standard deviation were 0.01mm to 0.03mm in Trilogy cups and Multipolar cup, except 44mm Trilogy model with 3mm wear. In HGP2 cups, average errors were about 0.07mm and standard deviation were 0.04mm to 0.07mm.

Discussion
Automatic linear wear measurements of metal-backed cups with 3D spiral CT were performed successfully. Average error of 0.05mm in BHP, 0.05mm in Trilogy cups and 0.07mm in HGP2 cups are superior in comparison with other reports of in-vivo wear measurements 1-3). In 44 mm Trilogy cup, 3mm wear model had larger error of maximum 0.2mm. Thin polyethylene liner would cause interference of residual artifacts in CT image and made larger error. Standard deviation of penetration measurement being 0.02mm in BHP, 0.05mm in Trilogy cups and 0.07mm in HGP2 cups will be enough reproducibility in clinical use. We used cups with multiple holes in this study, which would result in rather inferior reproducibility than BHP. Better performance is estimated with non-hole cups. High contrast of metallic substance and simple shape of the objects would be the reasons of the accuracy. Digital and automatic process should have enough reproducibility without any inter or intra observer error. Although data feedback from revision or cadaveric study is necessary to examine true clinical accuracy, we expect similar performance as laboratory data. Accurate and reproducible wear measurement with 3DCT will be a useful tool to evaluate clinical performances of polyethylene liners earlier.

References

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