7-2007

Development and Analysis of a Software Package to Quantify In Vivo Polyethylene Wear after Total Hip Arthroplasty

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DEVELOPMENT AND ANALYSIS OF A SOFTWARE PACKAGE TO QUANTIFY *IN VIVO* POLYETHYLENE WEAR AFTER TOTAL HIP ARTHROPLASTY

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Introduction

Since the first total hip arthroplasty (THA) in 1938, THA evolved and developed into one of the major concentrations of orthopaedic research. The typical hip implant device used today incorporates a femoral and an acetabular component that serve to replicate the anatomical and mechanical functions of the natural hip joint. However, several problems exist that can effect the function of the implant device. Wear in the polyethylene liner of the acetabular component of the total hip replacement device is known as one of the major factors that affects the longevity of total hip replacement devices. Both manual and computer-aided techniques have been developed to measure linear and volumetric polyethylene wear in two and three-dimensional directions. This study aims to develop a software package that will accurately measure *in vivo* polyethylene wear after total hip arthroplasty and can be applied to determine the factors that lead to polyethylene wear.

Methods

The measurement algorithm contained in the software package is based on the roentgen stereophotogrammetric analysis (RSA) developed by Dr. Göran Selvik in 1989. RSA is a highly precise technique of measurement designed to detect the three-dimensional change in the relative positions of rigid bodies from two-dimensional images. RSA can be easily applied to the measurement of polyethylene wear. A calibration cage containing a set of fourteen fiducial beads and a set of fourteen control beads is used to establish the coordinate system for the RSA algorithm.

The software package was designed and developed on a C++ platform using Microsoft Visual C++ .Net software (for Windows 2000 and XP). It is composed of two different programs, rsa_tools and rsa_test. The rsa_tools program is a graphical interface that allows the user to view and interact with digitized radiograph images in TIFF (*.tif), JPEG (*.jpeg, *.jpg), and Bitmap (*.bmp) formats. The rsa_test program is a computational program that contains the least squares algorithms used to perform all of the transformations necessary in determining the three-dimensional locations of the rigid bodies from the two-dimensional images. The rsa_test program produces a radius value to represent the thickness of the polyethylene liner. The radii values are compared between points in time to determine the polyethylene wear that has occurred.

Two testing methods were developed to determine the accuracy of the software package, an implant measurement comparison and a "zero-wear" test case. A Protasul (Sulzer Medica) THA implant was radiographed at two points in time from two x-ray sources or views, creating a situation in which there is "zero-wear" on the polyethylene liner. The radiograph images were digitized using a Microtek ScanMaker 9800XL (Microtek USA, Carson, CA) at 300 ppi resolution. The implant measurement comparison method was conducted by measuring four distinct distances on the implant device with both a caliper and the software package. The measurements were compared statistically to determine the accuracy of the software. The "zero-wear" test case evaluated the measurement algorithm's precision in measuring *in vivo* polyethylene wear. A series of three trials were performed and the results were compared statistically.

Results

The measurements taken by the caliper and the software package (Time 1, Time 2) during the implant measurement comparison method test were compared to show the accuracy of the program's measurement algorithm (Figure 1).

	|Time 1 – Time 2|	|Time 1 – Caliper|	|Time 2 – Caliper|
Acetabular Rim Diameter	0.0346"	0.0782"	0.1128"
Femoral Head Diameter	0.0215"	0.0325"	0.0110"
Femoral Neck Diameter	0.0046"	0.0090"	0.0136"
Flange – Tip Distance	0.0046"	0.0133"	0.0179"

Figure 1 – The calculated differences for the implant measurement comparison method

The measurements from the "zero-wear" test case were compared statistically to demonstrate the ability of the program to precisely measure polyethylene wear (Figure 2).

	Mean	Standard Deviation	Coefficient of Variance
Time 1	0.2628"	0.008106"	3.08%
Time 2	0.2658"	0.003955"	1.48%
in vivo Polyethylene Wear	0.003433"	0.003591"	1.05%

Figure 2 – The statistical comparison between measurements taken by the software in the "zero-wear" test case.

Discussion

The results of the two testing methods show that the software package is accurate, showing a small amount of discrepancy between its measurements and the caliper measurements, and precise, showing a small amount of uncertainty in the polyethylene wear measurements. The software program has achieved the goals of being developed as an accurate, precise, and efficient means for measuring *in vivo* polyethylene wear after total hip arthroplasty.

References

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Acknowledgments

This research was supported by the Department of Orthopaedic Surgery at the University of Texas Houston Health Science Center.