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Research Article

A New Automated Way to Measure Polyethylene Wear in THA Using a High Resolution CT Scanner: Method and Analysis

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As the most advantageous total hip arthroplasty (THA) operation is the first, timely replacement of only the liner is socially and economically important because the utilization of THA is increasing as younger and more active patients are receiving implants and they are living longer. Automatic algorithms were developed to infer liner wear by estimating the separation between the acetabular cup and femoral component head given a computed tomography (CT) volume. Two series of CT volumes of a hip phantom were acquired with the femoral component head placed at 14 different positions relative to the acetabular cup. The mean and standard deviation (SD) of the diameter of the acetabular cup and femoral component head, in addition to the range of error in the expected wear values and the repeatability of all the measurements, were calculated. The algorithms resulted in a mean (±SD) for the diameter of the acetabular cup of 54.21 (±0.011) mm and for the femoral component head of 22.09 (±0.02) mm. The wear error was ±0.1 mm and the repeatability was 0.077 mm. This approach is applicable clinically as it utilizes readily available computed tomography imaging systems and requires only five minutes of human interaction.

1. Introduction

Total hip arthroplasty (THA) devices are being utilized for longer periods of time as younger and more active patients receive them [1]. Although there are a variety of common reasons for long-term failure [2, 3], this study concerns only wear [4]. *In vivo* wear rates of several different acetabular cups, with and without polyethylene liners, have been reported [5–13] with the most recent liner wear rates ranging from 0.037 mm/year to 0.005 mm/year and total wear at revision being about 1.0 to 3.5 mm. Higher precision and accuracy of wear assessment methods would shorten the time for clinical studies of new implants and enable detection of clinically significant wear [14].

Previously our group showed that CT volumes can be used to evaluate acetabular cup position and migration in hip phantoms and patients [15, 16] and to determine 3D migration of the femoral component head into the acetabular cup at 1 mm, later reduced to 0.51 mm [17]. However, this required considerable user interaction time as about 200 landmarks (points) had to be placed on the 3D surfaces of the femoral component head and acetabular cup.

Here the interaction time to choose landmarks is reduced by limiting the number of landmarks to a total of seven (requiring only five minutes on average per CT volume) and the skill level of the operator was reduced. Surfaces were automatically extracted based on these landmarks plus a threshold for the electron density of the prosthetic material; the center and diameter of the prosthetic components viewed as (parts of) spheres were automatically determined, and from these centers, the distance between the acetabular cup and femoral