Author's response to reviews

Title: THR Simulator - The Software for Generating Radiographs of THR Prosthesis

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Author's response to reviews: see over
Dear editor:

Thank you for giving us the opportunity for second revision. We have done a major modification according to reviewers’ questions. Our answers to the questions are listed below. We hope you could accept our manuscript.

Best wishes.

Corresponding author.

Chen-Kun Liaw.
For reviewer: Ales Iglic

Thank you for reviewing our manuscript and providing the valuable suggestions.

1. The title of the manuscript "THR Simulator - The Software for generating Radiographs of THR Prosthesis", the first sentence in the abstract "Measuring the orientation of acetabular cup after total hip replacement ....." and also the first sentence of the main text (line 54) "Measuring of orientation of acetabulum cup and wearing ...." (and many other sentences) imply that the main subject of the work is determination of orientation of acetabular cup and wearing, i.e. the text of the manuscript is misleading. From the comments of the second referee it can be concluded that he got the same impression that acetabular orientation and wear could be determined using the authors´ program.

**Answer:**
We intended to direct the readers from well-known issues (cup orientation and wearing) to our issue (simulation). However, we change the second sentence in background section so that readers may not be misled.

**Text change:**
(In Background section, lines 52 to 53)
Verifying the measuring orientation and wearing methods are both important, which may require a simulator to simulate every situation for such an analysis.

2. The authors also wrote in their answer to the comments of the referees that "Our program is designed to generate radiographs of acetabulum and femoral head with known orientation and position ...." and "We will develop a program to measure cup orientation and wear in the coming months". Nevertheless, I believe that the authors somehow determined the orientation of the cup in order to produce Figure 2. Therefore the method how they determine the orientation of the cup should be clearly described in the text, especially at Fig.2, otherwise according to my opinion, the present version the manuscript can not be published.

**Answer:**
We do have an invention (see reference #1) about measuring orientation. We have added one figure and one sentence to the text.

**Text change:**
(In Results and Discussion section, lines 185 to 186)
Figure 4 shows how to measure the cup orientation with our invented method.

(In Figure Legands, lines 285 to 289)
Figure 4. The simulated radiograph is printed in paper and is measured with our
previously published method. We align the baseline of the protractor with the long axis of the ellipse, and then read the anteversion at the mid-point of the ellipse, meanwhile we read the inclination at the horizontal line on the upper part of the protractor. In this case the anteversion is $9^\circ$ and inclination is $45^\circ$.

3. In addition, if the authors need only a few months to develop their new program to measure the cup orientation and the acetabular wear (as they claimed in their letter), I would strongly suggest to do this and only then resubmit the manuscript. Only in this case the authors could write (as it is written now on line 210): "We design a new software THR Simulator that can generate pelvis radiographs after total hip replacement".

Answer:
There are softwares to measure the cup orientation and the acetabular wear. Most PACS venders will provide the software sold with their system. The other reviewer, Robert H Hopper, has mentioned that they used “Martell's Hip Analysis Suite” for such researches. We also added a new reference (reference#14), in which the authors compared four computerized methods of measuring wear. Developing such a program might be a repeat of previous people’s work. To our knowledge, the THR simulator is rather innovative because no one has ever done it before.

4. The authors used upper, medial and posterior movement to indicate wearing of three directions (lines 200-201). However, for long term influence of wear on the status of the hip after total hip replacement, the volumetric wear (which determines the number of polyethylene microparticles in the surrounding tissue) is actually important (and not the linear wear). Therefore the authors should estimate from their data (indicating the linear wear) also the volumetric wear, for example by using the simple method described in the paper of Kosak et al., Skeletal Radiol., 32:679-686, 2003.

Answer:
Thank you for the comments, we have added it into our discussion section.

Text change:
(In Discussion section, lines 201 to 202)
Calculate wearing volume is another interesting issue. Kosak et al. has published a mathematical model to calculate it with the three wearing directions.\textsuperscript{19}

5. The authors’ standpoints that "The mathematical model is both time- and page-consuming to be explained in detail." and "In fact, we do afraid that the explanation will explain nothing but raise more questions for reader." are not scientific. If the additional explanation "will explain nothing" this just means that the authors are not
capable to explain their own model in clear and distinctive way. Also it seems that the authors are afraid that the readers will "raise more questions".

**Answer:**
We apologize to mention these seemly unscientific sentences in our previous answer. We did have described in our manuscript the mathematical model in detail in the previous revision.
(In Implementation section, lines 94 to 133)

Our goal is to build a simulated total hip prosthesis. Virtually, femoral head equals to a ball.

\[ x^2+y^2+z^2<r_f^2 \]  \hspace{1cm} (2)

where \( x, y, z \) are the point of the simulated three-dimensional Cartesian coordinate system, \( r_f \) is the radius of femoral head.

In our program, we make the ball move to simulate wearing of insert.

\[(x-d_x)^2+(y-d_y)^2+(z-d_z)^2<r_f^2 \]  \hspace{1cm} (3)

where \( d_x, d_y, d_z \) are femoral head movement in three directions.

Virtually, acetabulum is composed of two balls and one plane.

\[ x^2+y^2+z^2<r_{ao}^2 \]  \hspace{1cm} (4)
\[ x^2+y^2+z^2>r_{io}^2 \]  \hspace{1cm} (5)
\[ ax+by+cz>0 \]  \hspace{1cm} (6)

where \( r_{ao} \) means radius of acetabulum’s outer shell, \( r_{io} \) means radius of acetabulum’s inner shell, \((a,b,c)\) means the normal vector of the acetabulum which can be derived from inclination and anteversion of acetabulum. Liaw et al. derived the following formula for this process.\(^{17}\)

\[
\text{vector } n = ( \sin\phi\times\cos\theta, -\cos\phi\times\cos\theta, \sin\theta) \hspace{1cm} (6.1)
\]

where vector \( n \) means the normal vector of the acetabulum, \( \phi \) means the inclination of acetabulum, \( \theta \) means the anteversion of acetabulum, positive \( \theta \) means anteversion, and negative \( \theta \) means retroversion.

Theoretically, the X-ray source is set at \((0,0,-d_t)\). \( d_t \) means tube distance (the X-ray
tube to the acetabulum center). The points at film are \((x_f, y_f, d_f)\). \((x_f, y_f)\) means point at film. 
\(d_f\) means distance from film to the acetabulum center.

\[
(t \cdot x_f, t \cdot y_f, t(d_f + d_t) - d_t) \quad 0 < t < 1 
\]

(7)

The ray-tracing algorithm means calculating every ray from X-ray source to film. We used formula (7), simulating every X-ray from source to film. We then estimated the total length the X-ray beam passed through femoral head by calculating the length between the two extreme solutions of formulas (3) and (7). Finally, we came out at the total length the X-ray beam passed through acetabulum by calculating length between the two extreme solutions of formulas (4), (5), (6), and (7). We use analytical mathematics for these calculations.

6. The authors' program should be compared with other methods. The answer that "Our program is designed for producing radiographs with known parameters" is certainly not the argument against the above suggestion of the second referee. 

**Answer:**

The only comparable model is mechanical model, which is not available. It has been used in one study (see reference #7). Without comparable mechanical model, we turn to verify our program with our previous studies (see reference #1 and #18). The precision were acceptable in these two studies.

7. Everybody who will use the authors´ program should determine the cup orientation, as did also the authors if they wanted to produce Fig.2. Therefore the authors should compare their results with the results of other models regardless if they are using their own method to determine the cup orientation (they wrote that they will do this in "coming months") or some other method which is described in the literature.

**Answer:**

We have done these researches previously (see reference #1 and #18). We have added one figure for demonstration.

**Text change:**

(In Results and Discussion section, lines 185 to 186)

Figure 4 shows how to measure the cup orientation with our invented method.

(In Figure Legands, lines 285 to 289)

Figure 4. The simulated radiograph is printed in paper and is measured with our previously published method. We align the baseline of the protractor with the long axis of
the ellipse, and then read the anteversion at the mid-point of the ellipse, meanwhile we read the inclination at the horizontal line on the upper part of the protractor. In this case the anteversion is 9° and inclination is 45°.

8. If the authors think (based on the Beer-Lambert law) that their dependency in Fig.3 is exponential, then they should fit the experimental points by using the appropriate exponential function and not just connect the points by lines as it is done in the present version of Fig.3.

Answer:
Thank you for reminding us this valuable suggestion. We fit the function with exponential function and found the results to be better. Some striations were removed. The femoral head was seen (unable to be seen in previous version) in acetabular shell.

Text change:
(In Implementation section lines 87 to 93)
Because too many parameters needed to be controlled to build up the software program, we tried another solution. We first took X-ray (63kv, 17mas) on the step-wedge phantom, made of titanium, with 5 steps with an increment of 1 mm thickness from 1 to 5 mm [Figure 3]. Such a step-wedge phantom film was scanned. The grey levels on this X-ray radiogram were mapped as the optical density values. We measured the optical density of each of the 5 wedges as well as that of the film background. The mapping function, from metal width to greyscale, is fit by exponential function. The mapping function is shown in Figure 3.

(In Figure Legends section lines 280 to 283)
Figure 3. (↑↑↑)The phantom, which is made of titanium with thickness from 1mm to 5mm. (↑↑)The corresponding photodensity on the radiographs of the phantom is shown.

(↑)The mapping function (from thickness to grey scale). We fit the experimental points with an exponential function.
For reviewer: Robert H Hopper

Thank you for reviewing our manuscript and providing the valuable suggestions.

1. The version of the THR Simulator software that I downloaded with the revised manuscript had changed the units for head movement to microns, but the maximum value that I could specify was 11. As a consequence, the femoral head never appeared to move in any of the simulations I attempted. It appears that the authors may need to modify the program to remove the limit imposed on the femoral head movement. Since the possible range of femoral head movements in microns could be quite large, it might be easier to allow the user to enter a value instead of using the arrows on the graphical interface to scroll through values.

**Answer:**
We set the limitation that the maximal wearing is wearing through the polyethylene. Your situation could be that you set other directional movements too much, thus limiting the wearing. We have been tested it repeatedly. In Figure 1, we have set the wearing parameters at 4000, 5000, and 6000(μm). It worked well.

2. Line 118: Can the authors provide a reference that specifies how the constants "a", "b" and "c" are mathematically related to the abduction and anteversion angles specified by the user in the THR Simulator program? Alternately, if a reference is not available, it might be useful to include equations relating these quantities in an Appendix. I do not think that these equations should be included in the text of the manuscript unless they are fairly simple. If an Appendix is incorporated, it could also include the solutions to equations (3) and (7) as well as the solutions to equations (4), (5), (6) and (7). It is not clear to me whether the authors solved these equations numerically or analytically.

**Answer:**
In our previous research, we calculated the vector from anteversion and abduction. The reference was included (reference#17). In that paper, we first converted anteversion and abduction to normal vector of acetabulum. We use the same process here.

We use analytical mathematics to solve these equations analytically.

**Text change:**
(In Implementation section, lines 115 to 121)
Liaw et al. derived the following formula for this process.\textsuperscript{17}

\[
\text{vector } n = (\sin \phi \cos \theta, -\cos \phi \cos \theta, \sin \theta) \quad (6.1)
\]

where vector \( n \) means the normal vector of the acetabulum, \( \phi \) means the inclination of acetabulum, \( \theta \) means the anteversion of acetabulum, positive \( \theta \) means anteversion, and negative \( \theta \) means retroversion.

(In Implementation section, lines 128 to 133)

The ray-tracing algorithm means calculating every ray from X-ray source to film. We used formula (7), simulating every X-ray from source to film. We then estimated the total length the X-ray beam passed through femoral head by calculating the length between the two extreme solutions of formulas (3) and (7). Finally, we came out at the total length the X-ray beam passed through acetabulum by calculating length between the two extreme solutions of formulas (4), (5), (6), and (7). We use analytical mathematics for these calculations.

3. If the authors do not wish to include the information requested in #2, would they consider making their source code available as part of the manuscript? The C++ code could be incorporated in another supplemental file. This would enable readers to examine the actual implementation of the authors' methods that are described in the text.

**Answer:**
We have included the formula and reference for the previous question. Thank you for reminding us.

4. Lines 132 and 134: Please replace "beam" for "bean".

**Answer:**
We apologize for our carelessness. Thank you so much for reminding us these two misspellings.

**Text change:**
(In Implementation section, lines 128 to 133)

The ray-tracing algorithm means calculating every ray from X-ray source to film. We used formula (7), simulating every X-ray from source to film. We then estimated the total length the X-ray beam passed through femoral head by calculating the length between the two extreme solutions of formulas (3) and (7). Finally, we came out at the total length the X-ray beam passed through acetabulum by calculating length between the
two extreme solutions of formulas (4), (5), (6), and (7). We use analytical mathematics for these calculations.

5. A recently published article compared several methods for measuring THA wear. The citation for that article is:


The authors may wish to include this citation on line 57 with references 7-13. It appears that some of the methods for measuring wear that were examined in this recently published study are accurate and freely available.

Answer:
Thank you for reminding us this new published manuscript. We have added it as reference#14.

Text change:
(In Reference section, lines 252 to 255)