Computer Assisted Implant Size Detection Algorithm for Total Hip Arthroplasty

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Abstract

Pre-operative planning is very important in the process of a Total Hip Arthroplasty (THA) because it is a method for determining the size and optimal implant position. Currently, a manual implant size detection technique of trial and error is used to determine the appropriate implant size for patients. By taking the full advantage of the digital X-ray and computer technology, we have introduced the new algorithm for implant size detection in THA pre-operative planning. This algorithm enables the surgeon to detect a digital femoral VERSYS stem and TRILOGY acetabular implant size automatically, then digitally overlay them over the digital X-ray image. A total of ten X-ray patients were randomly selected to test the accuracy and effectiveness of the developed algorithm. Results showed this algorithm predicted stem component size well, with 80% within ±1 size and acetabular component was predicted slightly better with 90% within ±2 component size.

Keywords: Implant, total hip arthroplasty, algorithm, size, detection, templating.

1. Introduction

Total hip arthroplasty (THA) is a proven and well-established method in the treatment of advanced degenerative joint disease [1]. According to experts from the Medical Center of Universiti Kebangsaan Malaysia (PPUKM), the conventional detection method was used to search for a suitable implant for the patient. The method involves using the implant templates supplied by the supplier (Zimmer) and then measuring the templates of the implant by doing image mapping on the patient’s general X-ray (film). This step is done repeatedly until the appropriate implant of the patient is encountered. However, the survey found that this procedure requires a long time, and is said to be less efficient [2]. The manual procedure requires a long time to determine the size of the patient’s implant because the method used is repeated several times [3][4]. Thus, the manual procedure should be changed to a digital technique, or, in another words, using software. Some studies have reviewed the utility of digital templating [5-8], but none of those studies used an automated algorithm or technique for implant size detection. This new algorithm will help the surgeon identify the appropriate implant size digitally and automatically.
2. Research Background

Total Hip Arthroplasty (THA) or Total Hip Replacement (THR) is a process in which the hip joints are replaced with artificial joints or implants. According to [9][10], THA is a surgical procedure which replaces the diseased cartilage and joint with artificial materials made of metal and plastic. The use of these implants is intended to help the patients in leading a normal life without any interference or pain in the joints when walking and performing daily activities. In anatomy, the hip joint comprises of a ball and socket joints. The socket is shaped like a cup of pelvic bones known as acetabulum which is connected with the end of the femur and shaped like a ball. Three main components involved in THA are stem, acetabular and ball. These components are designed to ensure that the metal will always rub on the plastic and cause a gentle movement and minimum erosion [2]. Figure 1 shows the implants images used in THA.

![Figure 1. Implant in THA](image)

2.1 Manual Pre-operative Planning in THA

There are several critical components of the pre-surgery evaluation, a comprehensive history and physical examination pre-surgical radiographs, and medical evaluation. Other plans including a sample of pre-surgery radiographs and selection of approach and surgical techniques. Preoperative radiograph is the critical part of pre-surgical preparation. This radiograph can determine the extent of joint artrosis and can also help identify some pathological conditions that require special pre-surgery consideration. The normal preoperative radiograph includes pelvis anteroposterior view. In addition, the proximal femur anteroposterior view helps in determining the femoral canal size for pre-surgery implant sizing. The leg position view also helps in proximal femoral sizing, and the cross-lateral view is the best to see acetabulum. To determine the optimum implant size for a patient, the implant templating on the
the patient’s image should be implemented.

Template refers to a standard guidelines used in shaping the framework of the bones. The orthopaedic specialists will use this template to match the X-ray image of a patient so that the optimum size can be determined. Templates are obtained from suppliers in accordance with each prosthetic design. Templates that are available from the Medical Center of Universiti Kebangsaan Malaysia (UKMMC) are zimmers with a magnification of 115% to 120%. This template is used manually by sticking it on the AP view radiographs to determine the appropriate size of the stem and acetabular. Figure 2 and figure 3 show the implant template used by orthopaedic specialists from UKMMC in THA process.

![Figure 2. Stem template](image1)

![Figure 3. Acetabular template](image2)

2.2 Manual Implant Templating
Prior to surgery, the template preparation process is very important because it is a screening process in which an orthopaedic specialist can determine the optimal implant size before surgery. The orthopaedic specialist will do the adjustment process of the implant templates first before bringing the results into the operating room. In the operating room, the orthopaedic specialist will make the final selection of the appropriate implant size. The use of implants in the template customization process on the X-ray image of a patient before surgery can provide important information to the orthopaedic specialist in determining the size of the implant to be used [11]. By using the manual method, any error in template transformation such as rotating and scaling while recording the patient's hip bone radiographs prior to the surgery will lead to errors in determining the size of implant templates. Thus, the templating process should be done cautiously. Figure 4 and figure 5 show the process of manual implant templating for femoral stem and acetabular [12].

![Figure 4. Manual templating for stem component](image1)

![Figure 5. Manual templating for acetabular component](image2)
3. Materials and Method

Detection algorithms that will be generated are based on conventional and computerized techniques in which the implant template will be matched to the X-ray images [9]. A trial and error method will be repeated several times until the appropriate size is found. The proposed new algorithm has the ability to detect the size of the implant in automation. By using the concept of distance between two points, hip implants will be selected based on the femur size. Figure 6 and figure 7 show the proposed algorithm for a stem and acetabular implant size detection technique [13][14].

1.0: Draw a line on the femur.
2.0: Calculate the distance of the line.
3.0: The implant size is chosen based on the distance of that point.
   3.1 If the distance of <9mm and> 20mm, no implant will be displayed
   3.2 If the distance has a decimal value, take the previous value.
4.0: Displayed stem implant

**Figure 6. Stem implant detection algorithm**

1.0: Draw a line on acetabulum diameter.
2.0: Calculate the distance of the line.
3.0: Size of the implant is chosen based on:
   3.1 If the distance of <36mm and> 80mm, no implant will be displayed.
   3.2 If the distance has a decimal value, take the previous value.
   3.3 If the distance has an odd value, take the previous even value.
4.0: Display acetabular implant

**Figure 7. Acetabular implant size detection algorithm**

In the algorithm, as in figure 6, the first thing the user needs to do is draw a line on the patient’s femur X-ray. The distance between two points on the line will be used to determine the size of the implant. If the distance is less than 9 mm or more than 20 mm, the implant will not be displayed. This is because the VERSYS stem implant produced by Zimmer comes only in size from 9 mm to 20 mm. Take the previous value if the distance has a decimal value. For example, in figure 4, the line distance drawn on the femur was 14.39 mm (yellow circle), so the value to be taken is 14 mm. Stem implant 14 mm in size will be displayed on the X-ray images.
Figure 8. Line drawn on the femur (yellow circle) and acetabulum (red circle)

In the algorithm shown in figure 7, the user must draw a line on the acetabulum diameter. Line distance will be calculated, and the size of the implant will be determined by the acetabulum diameter size. Sizing method involves three conditions, namely, if the size of the implant is smaller than 36 mm or larger than 80 mm, then the implant will not be displayed. This is because the TRILOGY acetabular system implant comes only in size from 36 mm to 80 mm. In addition, if the distance has a decimal value, the previous value will be taken. For example, in figure 8, the distance of the line drawn on the acetabulum diameter is 64.15 mm (red circle), therefore the value will be taken as 64 mm.

4. Results and Discussion
4.1 Stem Implant Detection.

Based on the algorithm in figure 6, the first thing the user needs to do is draw a line on the patient’s femur X-ray. Figure 9 shows how to draw the line.

Figure 9. Line drawn on the femur
The distance between two points on the line will be calculated to determine the size of the stem implant. In figure 9, the distance drawn on the femur was 15.69 mm, so the value to be taken is 15 mm. Stem implant with 15 mm size will be displayed automatically on the X-ray image (see figure 10).

![Figure 10. Stem implant displayed on the X-ray](image)

4.2 Acetabular Implant Detection

Similar to stem implant, the first thing the user needs to do is draw a straight line on the patient’s acetabulum diameter. Figure 11 shows how to draw the line.

![Figure 11. Straight line drawn on the acetabulum diameter](image)
The distance between two points on the line will be calculated to determine the size of the acetabular implant. In figure 11, the distance drawn on the acetabulum diameter was 50.68 mm, so the value to be taken is 50 mm. An acetabular implant with 50 mm size will be displayed automatically on the X-ray image (see figure 12).

![Figure 12. Acetabular implant displayed on X-ray](image)

The size of the acetabular supplied by the PPUKM is an even number, so if there is an odd number, the even value before the odd value will be taken as the size of the acetabular implant. For example, if the distance drawn was 61.25 mm, so the value to be taken is 60 mm.

### 4.3 Algorithm Testing

In order to test the accuracy of the developed algorithm, an experiment was conducted with assistance from an experienced surgeon through the conventional method to determine the stem implant size. The results through the conventional approach were compared to the results produced by our automated algorithm. The testing recorded the implant size to be used and the time taken by both methods. For both implant component, ten randomly selected X-rays of unidentified patients were used for templating for both techniques.

For each X-ray sample, the optimal implant sizes determined by both methods were recorded. The difference between the two sizes was calculated and shown in Table 1. It is evident that the new algorithm yields very close results to those obtained through the conventional method in all ten studies. The difference, if any, is also within the error of clinically acceptable range (±1 mm size for stem, ±2 mm for acetabular) obtained through the conventional templating method. In addition, the study also demonstrated that the average time taken for implant templating in THA pre-operative planning using an automated technique was much less than when using the manual method.
Table 1. Manual vs digital

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5. Conclusion

At the present time, digital and computer technology with digital outputs are improving slowly but steadily in the medical centre [15]. Pre-operative templating has been useful to determine the optimum size prosthesis in total hip arthroplasty (THA) surgery. With classical tracing paper now obsolete, we have developed a new algorithm to undertake an automated templating procedure with digital implant and X-ray. This new algorithm offers a simple solution to the problem of using a conventional method in THA. The algorithm allows users to choose the stem and acetabular implant automatically on computer prior to surgery based on femur and acetabulum size. The new proposed implant detection algorithm also provides user-friendly and accurate computer programming surgical planning.

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