Computer Aided Preoperative Planning Application for Shoulder Hemiarthroplasty

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ABSTRACT

This paper describes a proposed CAD graphics application that analyze digital radiography image for preoperative surgery in shoulder hemiarthroplasty. The purpose of designing this application is to aid orthopedic surgeon in preoperative planning phase before surgery, in terms of selecting suitable implant and manipulating the digital radiograph by using various facilities or tools available in the application. Therefore, digital templating and image processing play important roles in this research. Basically this application will support a few types of image file including jpg, gif, bmp and etc to be loaded. It will allow image enhancement and also enable measurement tools to be used by surgeon during the preoperative phase. A user will only need to do 5 simple steps in order to get the appropriate template and finally generate reports that he requires.

Keywords
Digital Templating, Preoperative Planning, Shoulder Hemiarthroplasty

1.0 INTRODUCTION

This is an on-going research between orthopedic surgeons and programmers on developing a pre-operative templating and planning application for orthopedic procedures. In the past, templating has been performed by overlaying magnified rulers and transparent outlines of implants on the X-ray film (King, Craig, Boreham, Majeed & Moran, 2008). It is aimed that this application will takes away the ability to do routine pre-surgical templating, and enable surgeons to plan operations on-screen and facilitate the completely film-free orthopedic department in the most efficient and simple way.

1.1 Shoulder

The shoulder is a ball-and-socket joint that allows the arm to be raised, twisted, bent, and moved forward, to the side and backward. The head of the upper arm bone (humerus) is the ball, and a circular cavity (glenoid) in the shoulder blade (scapula) is the socket. A soft-tissue rim (labrum) surrounds and deepens the socket. The head of the humerus is also covered with a smooth, tough tissue (articular cartilage); and the joint, also called the acromioclavicular (AC) joint, has a thin inner lining (synovium) that facilitates movement while surrounding muscles and tendons provide stability and support. Most shoulder problems involve the soft tissues, muscles, ligaments, and tendons, rather than bones. And most of these problems fall into three major categories, tendinitis or bursitis, injury or instability and arthritis (Florian, Bernhard, & Juerg, 2008; William & Steven, 2005; Wiater, 2007). Either surgical or nonsurgical treatment will be suggested by specialist depending on how serious the illness is. One of the common treatments will be shoulder arthroplasty.

1.2 Shoulder Arthroplasty

Many people know someone with an artificial knee or hip joint. Shoulder replacement is less common. But it is just as successful in relieving joint pain. It is being used as a treatment for severe shoulder fractures. Over the years, this surgery has come to be used for many other painful conditions of the shoulder (Wiater, 2007). Shoulder arthroplasty reliably relieves pain and improves function in the majority of patients with painful arthritic shoulders. Shoulder prostheses are now commonly used. Clinical results and patient's satisfaction level are usually good. The most commonly used types are humeral hemiarthroplasty, unconstrained total shoulder arthroplasty, and semiconstrained inversed shoulder prosthesis. Complications of shoulder arthroplasty depend on the prosthesis type used. Osteoarthritis, rheumatoid arthritis, complex fractures of the proximal humerus, osteonecrosis of the humeral head, irreparable tears of the rotator cuff with or without arthropathy ("cuff tear arthropathy"), and revisions of failed prosthesis are the most common reasons to perform shoulder arthroplasty (Florian et al., 2008; William et al., 2005; Michael, 2004).

1.3 Shoulder Hemiarthroplasty

Shoulder arthroplasty involves replacement of humeral and glenoid components. Shoulder hemiarthroplasty is a process where the fractured humeral head is replaced with a modular prosthesis. The procedure aims at an adequate reconstruction of shape and function of the shoulder (Ernst, Ulrich, Sandra, & Wolf, 2004). There are studies showing that most of the patients who suffered from shoulder pain felt relief as well as experienced improvement in abduction, internal rotation and external rotation (Matthew, Charles, & Bradford, 2008; Ian, Robert, & Sharon, 2005). Therefore a mandatory technique to choose a suitable implant for joint replacement is vital. And the technique that will be discussed here is digital templating which is the famous technique implement in most of the preoperative planning software today.

1.4 Digital Templating

A complete shoulder arthroplasty process includes preoperative planning, intraoperative surgery and postoperative rehabilitation, each phase plays an important role, lacking in any of these would be considered as an imperfection. Preoperative templating is advised as an important part of patient assessment whereby the operating surgeon will gain an idea beforehand of the optimal implant size and restore anatomy (Hossain, Lewis, & Sinha, 2008). Optimal implant size is essential for success of joint arthroplasty. The correct implant size will help in soft tissue balancing and optimal load transmission through the new joint (Lewis, Hossain, Mustafa, & Sinha, 2008). Digital preoperative planning enables the surgeon to select from a library of templates and electronically overlay them on an image. The surgeon can then perform the necessary measurements critical to the templating and preoperative planning process in a digital environment. The preoperative planning process is fast, precise and cost-efficient, and it provides a permanently archived record of the templating process (James, 2004). This is becoming increasingly important due to the large range of implants available and the limitations of any one hospital unit in stocking large inventories of implants (SP & DL, 2005). Without the ability to template radiographs there is a danger that during the operation the surgeon will select an unsuitable implant, use the incorrect size of implant, or discover that the correct size is not available (King et al., 2008).

2.0 ISSUE ON ANALOGUE VS DIGITAL TEMPLATING

The issue about precision of analogue or acetate and digital preoperative planning is nothing new. However, each of the techniques has its own researches output that proved its efficiency. So there is no specific theory that shows either digital or analogue templating is more efficient. Some studies claimed that analogue preoperative planning yielded more predictable results than digital planning and would give more accurate results if it is done by an experienced surgeon (Lewis et al., 2008; SP et al., 2005; Valle, Fernando, Nicole, & Eduardo, 2007). On the other hand, some studies showed that digital templating proved to be statistically, significantly more accurate compared to analogue templating. Combining digital radiography with digital templating has the potential to eliminate errors associated with the manual manipulation of acetate templates and analog radiographs. Digital templating was determined to be acceptably safe for preoperative planning in these studies (Hossain et al., 2008; Iorio, Siegel, Specht, Tilzey, Hartman, & Healy, 2008). Most of the references found are related to knee and hip arthroplasty, but the main concept of digital and acetate templating are the same for shoulder, knee and hip during preoperative planning stage. So we can assume that the findings for comparison of digital and plain radiography preoperative templating for shoulder, hip and knee are the same.

3.O APPLICATION DESIGN

To develop a suitable and effective digital templating application, we have interviewed few specialists from the orthopedic department (National University of Malaysia Medical Center). Techniques and tools needed to measure prosthesis for humeral head and humeral stem are identified through discussions with orthopedic specialists and also via literature reviews (King et al., 2008; Michael, 2004; Ernst et al., 2004; Matthew et al., 2008; James & Tom, 2003; Field, Fabian, Peter, & Russell, 1998). The results were then implemented in the proposed application. The magnification issue is something that we couldn't miss in digital templating, so the measurement involved in the system is very important. Calibration will be done at the development phase to get the correct measurement (Valle et al., 2007; (Todsaporn, Amnach, & Mitsuhashi, 2008; Nofrini, La Palombara, Marcacci, Martelli, & F. Iacono, 2000). Figure 1 shows the proposed framework of the computer aided preoperative planning application.

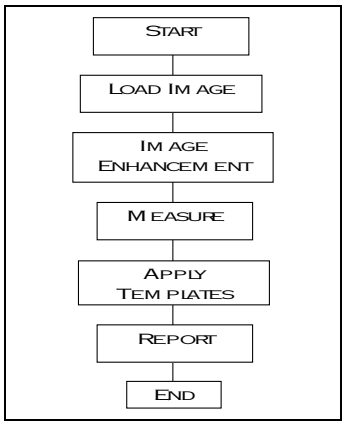

Figure 1: Framework Workflow

Basically, the application that will be built allows user to load image, followed by image enhancement with the support of a few image processing tools. Next, user only needs to perform five simple steps in order to get the appropriate template. The system will automatically process inputs made by user and select an output template with the closest fit in size according to the calculation result, and display it on the screen (all the template sizes available would be stored in a database and the application would automatically generate the template only after user had given the complete set of dimensions needed). Once a template is chosen, it can be easily scaled and manipulated manually by the user through the facilities available in the application. Finally, the user can choose to print out a report that will show the x-ray together with the digital template as well as information such as patient details, template size chosen, and surgeon's name.

3.1 Load Image

2D x-ray data from file type jpg, Gif, bmp and etc. can be imported to the application. After the image is successfully loaded, the next stage will be image enhancement.

3.2 Image Enhancement

At this stage, a best view of the x-ray on screen will be adjusted to enhance x-ray visibility and increase the accuracy of measurement by user. To get the perfect way for setting best view, a test is done on an x-ray image by using image processing functions in Photoshop. It is observed that to get the best quality and clear view so that the structure of the bone will be more visible, color inverting on X-ray image is required. Figure 2a and 2b show the difference before and after inverting an x-ray image. Therefore, color inverting on X-ray image is suggested before moving to the next stage, this is because after the inverting process, the user can easily locate parts of shoulder anatomy such as greater and lower tuberosities, humeral head, clavicle and etcetera for accurate measurements. The rest of image enhancement will be dependent on user's requirement in adjusting scale, brightness, hue/saturation, color editing and etcetera.

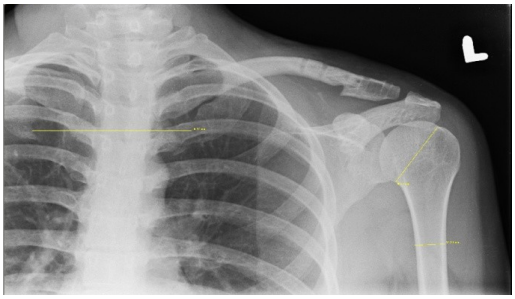

Figure 2a: X-ray image before invert color

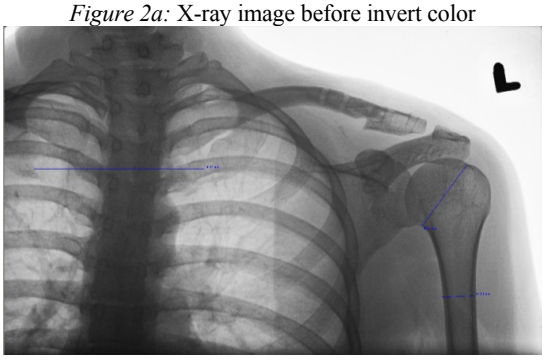

Figure 2b: X-ray image after invert color

3.3 Measure

Useful measurement tools include distance, angles and pattern matching (Thian Seng, Abdul Yazid, & al., 2008). These are preliminary planning phases for choosing a prosthesis template. Figure 3 shows measurements involve in getting the accurate implant for humeral head and humeral stem. In the picture, number 1-5 show the five steps that a user needs to perform in order to get proper template. First, user needs to draw a line across greater and lower tuberosities (no. 1 to 2 or vice versa). The system will automatically generate a semicircle once it registers the line (the semicircle indicates the round surface of humeral head). Next, the user will adjust the size of semicircle until it best fits the humeral head (as indicated by no. 1 and 2 in Figure 3). Finally user needs to draw two lines (lines 4 and 5) to get the humeral stem template.

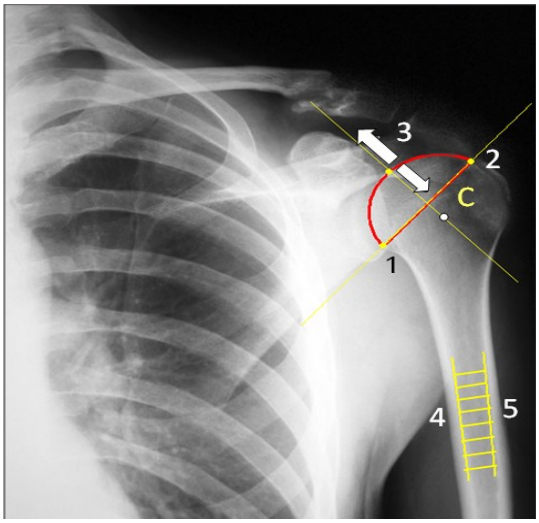

Figure 3: Five steps to get the template

3.4 Apply Template

Once user has finished providing the required inputs, the application will search the preloaded database and display the most appropriate template that is available in the database. User can then easily edit the template to best fit his needs.

3.5 Report

The final step in the workflow will be report generation. The application allows user to generate a comprehensive report, including a preoperative planning image produced by the system, annotations by the surgeon on the image using tools available in the application in the planning phase, and patient's details. The report can be either kept in softcopy or printed out as hardcopy for future reference.

4.0 CONCLUSION

This paper describes a proposed application for digital preoperative planning, begins with some general introductions of related topics in this research, followed by the some issue on digital templating regarding the reliability of analogue and digital templating. It then described the proposed application design and a workflow of the proposed application was shown in that case.

Acknowledgements

This is an ongoing research under a research group; there are currently two other similar researches on knee and hip arthroplasty. The proposed application will be developed and then used and tested by orthopedic surgeon to evaluate its efficiency, accuracy and flexibility.

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