CONVENTIONAL VERSUS DIGITAL PREOPERATIVE TEMPLATING IN PRIMARY TOTAL HIP ARTHROPLASTY AT HOSPITAL SULTANAH BAHIYAH

DR. KHOH PHAIK SHAN

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ABSTRAK

Pengenalan dan objektif:

Template adalah sebahagian daripada perancangan pra operasi dalam pembedahan sendi gantian pinggul. Kaedah konvensional dilakukan dengan filem telus asetat yang dibandingkan pada radiograf salinan keras.

Dengan kemunculan dan pelaksanaan radiograf digital , perisian template digital diperkenalkan pada arthroplasty pinggul.

Kami telah menjalankan kajian untuk membandingkan ketepatan teknik template konvensional dan teknik template digital di kalangan arthroplasty pinggul.

Metodologi:

Ini adalah satu kajian retrospektif dimana 73 pesakit yang menjalani pembedahan arthroplasty pinggul di Hospital Sultanah Bahiyah Alor Setar dari bulan Jun 2011- Jun 2014. Di masa yang berasingan, template konvensional dilakukan dengan menggunakan filem radiografi dengan template implan tertentu manakala template digital dilakukan dengan menggunakan perisian template TraumaCadTM pada stesen kerja komputer. Ujian *paired t test* digunakan untuk menentukan ketepatan template konvensional berbanding template digital. Kami juga menggunakan Kaedah Bland - Altman dan plot untuk menentukan persetujuan antara kaedah konvensional dan implan sebenar dan juga kaedah digital dan implan sebenar .

Keputusan:

Kedua-dua template konvensional dan digital mempunyai persetujuan yang baik dengan implan sebenar dalam meramalkan cawan acetabular dan saiz femoral . Walau bagaimanapun, template digital mempunyai persetujuan yang lebih tinggi untuk saiz implan sebenar berbanding template konvensional dalam meramalkan cawan acetabular dan saiz femoral .

Template konvensional meramalkan saiz cawan yang lebih kecil dengan ketara (P- value = 0.003) dan template digital meramalkan saiz cawan yang lebih besar tetapi tidak ketara secara statistik (P- value = 0,501) . Template konvensional dengan ketara meramalkan saiz femoral yang lebih besar (P- value = 0.004) manakala template digital juga meramalkan saiz femoral yang lebih besar tetapi tidak ketara secara statistik (P- value = 0,103) . Oleh itu template digital adalah lebih tepat daripada template konvensional dalam penilaian pra operasi .

Kesimpulan:

Template Digital adalah lebih tepat dalam meramalkan cawan acetabular dan saiz batang femoral daripada template konvensional

Kata kunci: Template, konvensional, digital, pembedahan arthroplasty pinggul

ABSTRACT

Introduction and objectives:

Templating is part of preoperative planning for total hip arthroplasty surgery. Conventionally this was done using on acetate transparent films overlaid on hard copy radiographs. With the emergence and implementation of digital radiograph, digital templating software was introduced in total hip arthroplasty.

We conducted the study to compare the accuracy of conventional templating techniques and digital templating techniques in primary total hip arthroplasty.

Methodology:

This was a retrospective study done on 73 cases where primary total hip arthroplasty was performed for osteoarthritis, avascular necrosis of femoral head and femoral neck fracture in Hospital Sultanah Bahiyah Alor Setar, Kedah, Malaysia from June 2011- June 2014. In a separate sitting, conventional templating was performed using hard copy radiographic films with implant specific templates whereas digital templating was performed using a magnification- calibrated digital radiographic images and TraumaCadTM templating software on a computer workstation. Paired t tests were used to determine the accuracy of conventional templating versus digital templating. We also used Bland-Altman Method and to determine the agreement between conventional method and actual implant as well as digital method and actual implant.

Results:

Both the conventional and digital template had quite a good agreement with the actual implant in predicting the acetabular cup and femoral stem size. However, digital templating had higher agreement to the actual implant size as compared to conventional templating in predicting the acetabular cup and femoral stem size.

Conventional templating significantly under predicted cup size (*P*-value = 0.003) and the digital templating slightly over predicted the cup size but was not statistically significant (*P*-value =0.501). Conventional templating significantly over predicted femoral stem size (*P*-value = 0.004) while digital templating slightly over predicted the femoral stem size but was not statistically significant (*P*-value =0.103). Therefore digital templating is more accurate than conventional templating in the preoperative assessment.

Conclusion:

Digital templating is more accurate in predicting the acetabular cup and femoral stem size than conventional templating using the available software.

Key words: Templating , conventional, digital, total hip arthroplasty

CHAPTER 1: INTRODUCTION

Total hip arthroplasty (THA) is one of surgical procedures for the treatment of hip dysplasia, arthritic disorders and fracture neck of femur. The goals for total hip arthroplasty are pain relief, restoration of range of motion, improvement of function, and restoration of normal hip biomechanics, and offset.

Proper positioning and orientation of acetabular and femoral components are important in determining the wear and durability of the implant hence patient's function and the long term success of the procedure. In addition, choosing the correct implant size can avoid subsidence with an inferiorly sized component, or fracture when a component is oversized. Therefore stepwise preoperative planning is an important and essential step in total hip arthroplasty surgery.

Templating is part of the preoperative planning in total hip arthroplasty surgery. It has been regarded for many years as an integral part of hip arthroplasty surgery (Capello 1986). Pre-operative templating allows estimation of the correct implant size, together with both the position and insertion depth of both acetabulum and femoral components. It also enables the surgeon to anticipate potential difficulties to reproduce hip biomechanics with the available implants (Scheerlinck, 2010). Inadequate planning can lead to several complications, including fractures, dislocation, insufficient offset, limb length discrepancy and failure of ingrowth (Gorski et al 1986, Knight et al 1986, White et al 2005).

Conventionally, preoperative templating was performed by overlying the transparent template (provided by implant manufacturer) on preoperative hard-copy radiographs placed on a radiograph view box. However with the emergence and implementation of picture archiving and communicating system (PACS) and digital radiography, this necessitates the development of digital templating software for preoperative purposes (Bono 2004). The digital templating software enables the surgeon to perform necessary measurements and preoperative planning in an entirely digital environment. Besides, digital templating also offers several advantages. First, the necessity of printing large and bulky films is eliminated. Second, digital radiographs can be stored more easily for quick access. Finally, the contrast and magnification possibilities of the images are usually excellent (Efe *et al.,* 2011).

To date, few studies from the west have evaluated the accuracy of digital templating in THA. Literatures from the Asian countries are lacking and most of our local hospitals are still practicing conventional templating techniques. The aim of this study was to determine the accuracy of templating techniques in term of conventional or digital methods in a local hospital. Accurate pre-operative planning in total hip arthroplasty enhances the surgeon’s ability to restore the hip biomechanics and lead to better long term outcome.

CHAPTER 2: LITERATURE REVIEW

2.1 Templating

Hip templating is the process of anticipating the size and position of implants prior to hip arthroplasty surgery. Hip templating is a systematic approach in estimating the size of the implants rather than guessing the size of the acetabular and femoral hip components prior to surgery (Scheerlinck, 2010).

Templating gives the surgeons an idea of the appropriate size, position and availability of these implants in the surgical theater and being able to anticipate possible errors during the surgery. In other words it provides a sense of security to surgeons. Besides knowing the appropriate size, templating also offers a good estimation of the offset to ensure adequate stability and reduce the wear rate (Sakalkale et al 2001, Devito*et al*., 2013).

2.2 Digital Pre-operative templating

Conventionally, preoperative templating was performed by overlying the transparent template (provided by the implant manufacturer) and preoperative hard-copy radiographs on a radiograph view box. As technology advances, there exists new digital software that enables up to do digital templating. The newer system utilizes soft copy radiographs and applies its digital templating software.

This option is favoured by some due to ease of storage and recall, and the printing of hard copy cumbersome films are no longer necessary (Efe *et al.*, 2011). In fact, in certain institutions, hard-copy film based radiographs may no longer exist.

2.3 Preoperative planning for primary total hip arthroplasty

Preoperative planning is an integral part of total hip arthroplasty. It familiarizes the surgeon with the patient anatomy prior to surgical procedure. With careful preoperative planning the surgeon is able to perform the procedure with precision, anticipate potential intraoperative problems, and with this achieve reproducible results (Della Valle *et al.,* 2005).

In the pre operative setup the surgeon integrates the general goals of arthroplasty with the patient's particular anatomy (Knight *et al*., 1992) and enables the surgeon to imagine the implant configuration in all three dimensions demanded during surgery (Muller 1992, Della Valle *et al*., 2005). The goals include the determination of the size and orientation of implants, optimizing the implant position and fit, conserving bone stock, downsizing for cement column mantle, restoring leg length, achieving an appropriate centre of rotation for the new implant and avoiding complications (Knight *et al*., 1992; Della Valle *et al.,* 2005).

Acetabular cup templating is necessary to optimize cup coverage and correct orientation. In a survey by Knight *et al* (1992) templating was useful to anticipate preoperative problems in 20% of cases. It allows the detection of any acetabular protrusion and the need for any bone grafting or osteophyte removal, and the potential use of any acetabular reinforcement device (Eggli *et al*., 1997).

Templating the femoral side for either cemented and cementless implants are aimed to optimize limb length discrepancies and femoral offset, thereby improving the overall biomechanics of the hip joint (Della Valle *et al*., 2005). Hip templating allows the restoration of the stem offset in 58-86% of cases and to also the position of the hip rotation centre within 5 mm, and leg length within 3 mm in 87-91% and 89% respectively (Della Valle *et al*., 2008). With femoral templating also, it allows us to detect if there is any coxa vara.

However, it could not anticipate 12% of technical problems such as acetabular rim fractures, cup misalignment and insufficient cup fixation, as well as femoral fractures and varus stem alignment.

2.4 Radiographic technique

A standardized radiographic evaluation of the hip for preoperative templating includes an anteroposterior (AP) view of the pelvis centered over the pubic symphysis. A perfect AP radiograph of the femur is needed to ensure the whole film is proportionate. The AP views are obtained with the patient lying supine on the table with the hips in 10° to 15° of internal rotation to show the true anteroposterior view of the proximal femur (correcting the physiologic anteversion of $10\text{-}15^{o}$) (Figure 2.1). The lower boundaries should include at least half of the femoral shaft.

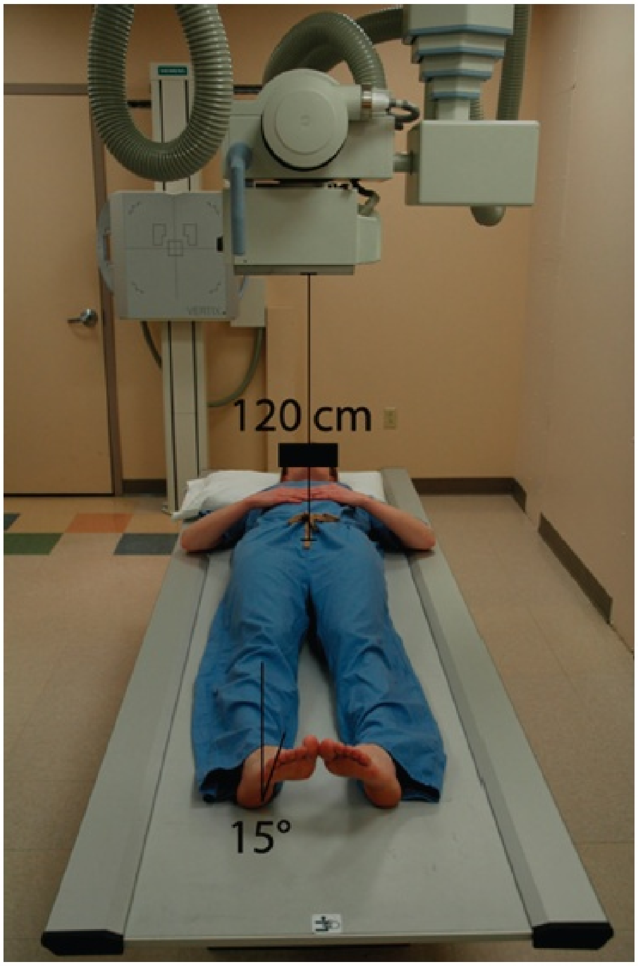

Figure 2.1: The positioning for an anteroposterior pelvic radiograph (taken from Clohisy*et al*., 2008)

An important factor in evaluating a preoperative planning procedure is ensuring the proper radiological magnification which is influenced by the distance between the patient and the film and the distance between the patient and the X-ray source (Figure 2.2) (Eggli *et al*., 1997).

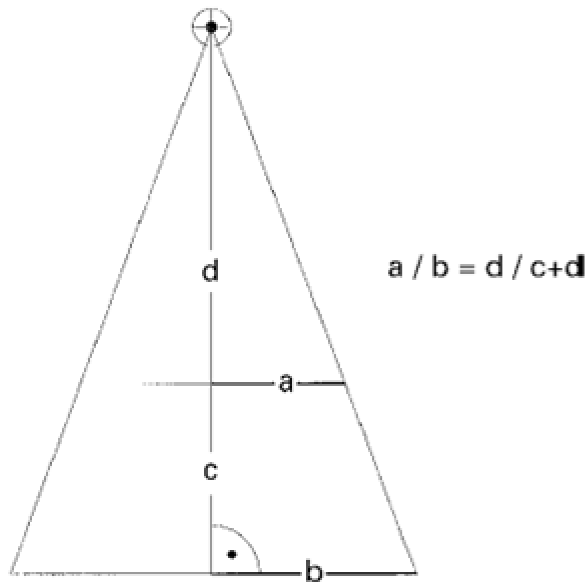

Figure 2.2: Relationship of distance and radiological magnification: According to the law of radiation, the magnification (b) of an object (a) is dependent on the distance between the object and the X-ray source (d) as well as the distance between the object and the X-ray film (c) (taken from Eggli *et al*., 1997)

Variations in the magnification can be eliminated by adjusting the distance from the X-ray source to each patient according to Table 2.1. Magnification is directly proportional to the distance between the pelvis and the film; therefore, increased magnification would be observed in obese patients and, conversely, less magnification in thin patients (Della Valle *et al*., 2005).

Distance object to film (cm)	**Distance camera to object (cm)**			
	100	**150**	**200**	**250**
10	1.10	1.07	1.05	1.04
20	1.20	1.13	1.10	1.08
30	1.30	1.20	1.15	1.12
40	1.40	1.27	1.20	1.16
50	1.50	1.33	1.25	1.20

Table 2.1: Magnification table calculated with different film-object and object-X-ray source distances (taken from Eggli *et al*., 1997)

With the use of digital radiograph images, a calibration device is required, usually in the form of a ball, in order for standardization of the magnification hence leading to the accuracy of the digital template. An object of a known size is projected on to the film is necessary to determine the magnification. A marker of standard size laid on the skin of the patient at the time of taking the preoperative radiograph may be used as a guide to calculate the magnification. For example a magnification marker like a coin with a known diameter can be taped to the patient's skin at the level of greater trochanter (Conn *et al*., 2002). Sinclair VF et al (2014) finds that by placing the calibration ball to the side of the hip, either between the patient's legs or lateral to the thigh, a small but unavoidable magnification error is introduced; hence it is important to place the marker on the same coronal plane of the hip to provide suitable accuracy.

2.5 Determining Radiographic Landmarks and Templating

There are a few radiographic landmarks that need to be identified on the acetabulum and they are the base of the teardrop, the ilioischial line, and the superolateral margin of the acetabulum for the acetabular component; while for the femur the medullary canal, the lesser and greater trochanters (Figure 2.3).

Delle Valle et al (2005) said that templating should follow the steps of surgery: which are templating the acetabular side first, followed by the femoral side. The first step in templating is to draw a horizontal reference line through the base of both teardrops. The teardrops are the most accurate anatomic landmarks because they are located close to the center of rotation of the hip joints (Della Valle *et al*., 2005).

Besides, there are few mechanical references that need to be identified during templating (Figure 2.4). Which are the hip, femoral and acetabular centre of rotation; acetabular and femoral offset; and the presence of any leg length discrepancy. The presence of any leg length discrepancy is determined by comparing the vertical distance between lesser trochanter to the tear drop line on their respective sides, and measuring the difference.

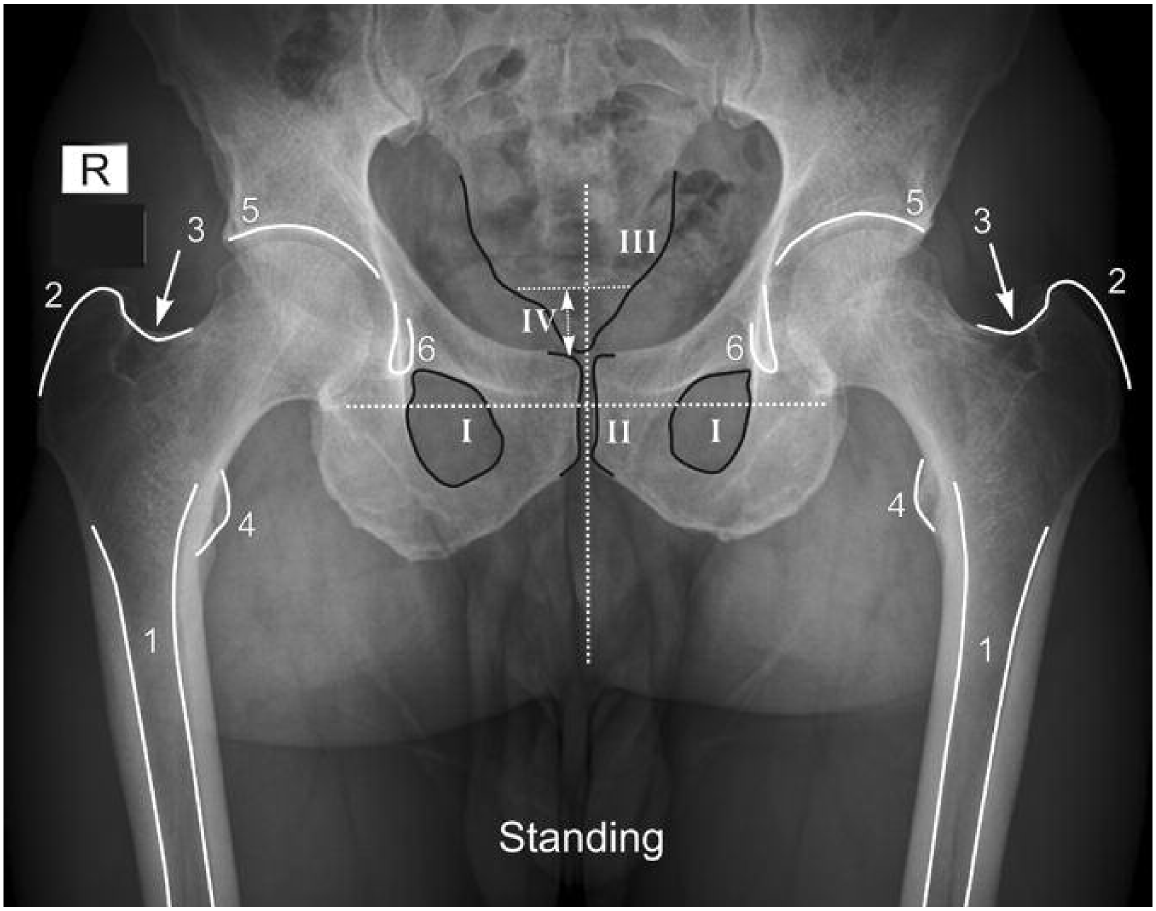

Figure 2.3: Standing anteroposterior pelvic radiograph suitable for hip templating. Anatomical landmarks : 1. Femoral shaft ; 2. Greater trochanter ; 3. “Saddle” ; 4. Lesser trochanter ; 5. Acetabular roof ; 6. Teardrop. (Illustration adapted from Scheerlinck, 2010)

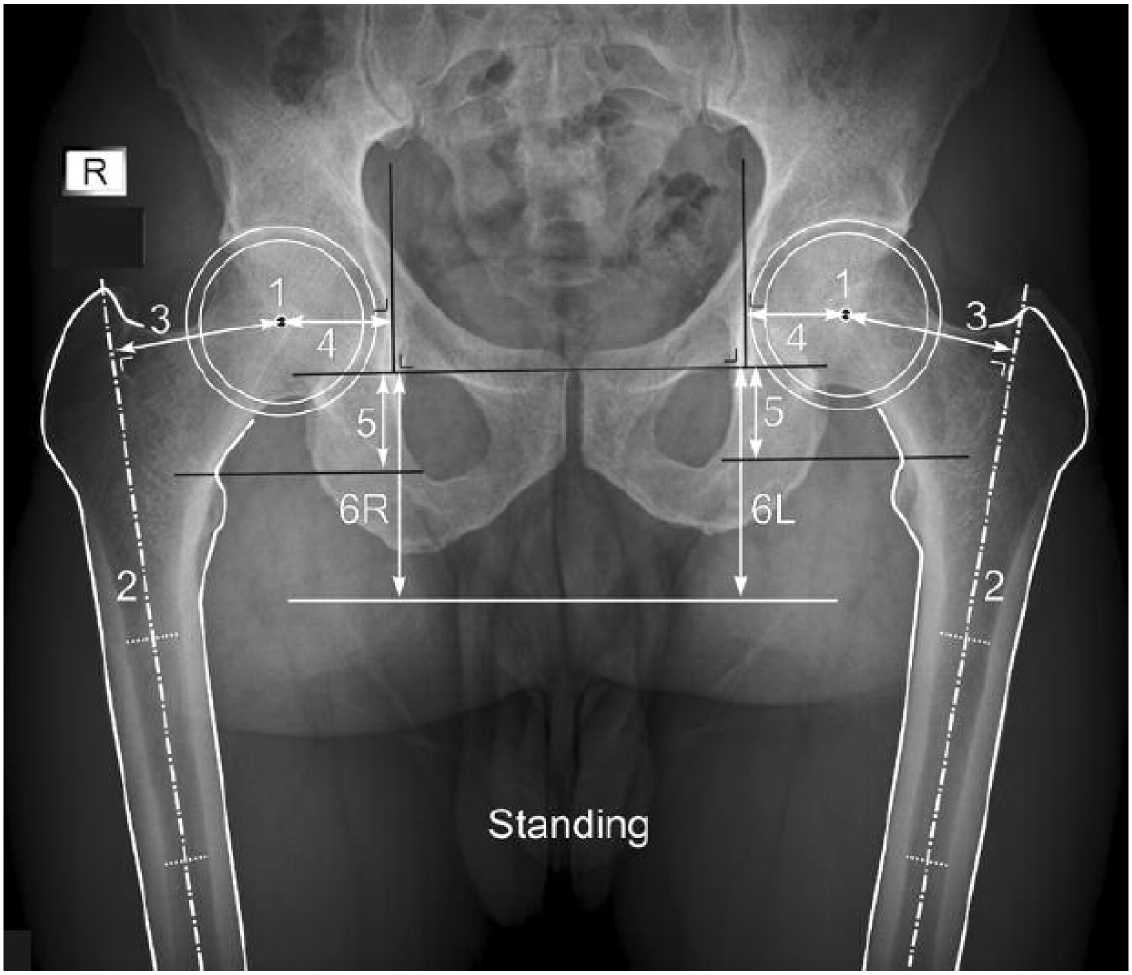

Figure 2.4: Mechanical landmarks : 1. Hip rotation centre ; 2. Longitudinal axis of the proximal femur ; 3. Femoral offset ; 4. Acetabular offset ; 5. Hip length. 6. The “leg length discrepancy” is calculated as the difference between the distances 6L and 6R. (Illustration adapted from Scheerlinck, 2010)

2.6 Acetabular Templating

The first step is for the cup chosen should fit the acetabular cavity well and to restore the original acetabular rotation centre. Proper positioning of the acetabular component with anatomical landmarks as guides may reduce the incidence of dislocation from inaccurate acetabular orientation (Sotereanos *et al*., 2006). On the acetabular side, the acetabular roof and the "teardrop" are adequate landmarks. The acetabular roof, especially the superolateral corner, is easily identified during surgery. The "teardrop" is a radiographic landmark created by the overlap of the most distal part of the medial wall of the acetabulum with the tip of the anterior and posterior horn of the acetabulum (Bowerman *et al*., 1982). During surgery, the most distal aspect of the teardrop corresponds to the most medial and distal part of the acetabulum, behind the transverse ligament and at the superior border of the foramen obturatum (Scheerlinck, 2010). The teardrop was selected as a landmark for referencing of acetabular templating because it had proven to be the anatomical landmark least affected by pelvic rotation and tilt (Goodman *et al* 1988, Massin *et al* 1989)

The cup should be positioned so that when the template is placed with the cup at 40° ± 10° of abduction, the medial border is near the the ilioischial line and the cup has adequate coverage of lateral bone, with minimal removal of the supportive subchondral bone (Della Valle *et al*., 2005). With the acetabular template in place, the center of rotation should be marked on the radiographs (Figure 2.5).

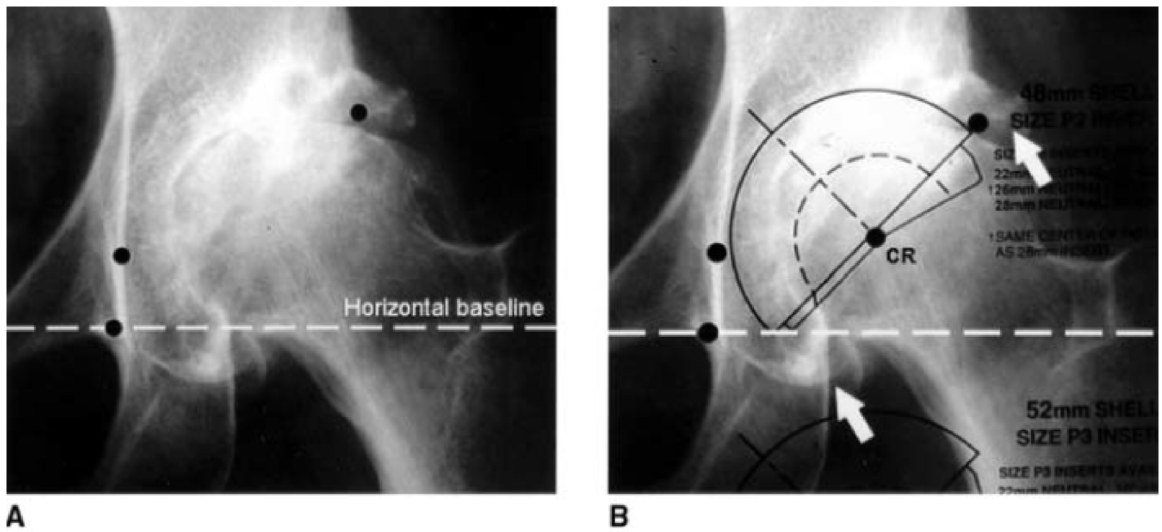

Figure 2.5: Acetabular templating: A- Acetabular templating begins by drawing a horizontal reference line though the base of the teardrops and by identifying three anatomic landmarks: the base of the teardrop, the ilioischial line, and the superolateral margin of the acetabulum (blackdots). B- With the cup template placed in relation to the anatomic landmarks, the center of rotation (CR) of the arthroplasty is marked. Osteophytes (white arrows) to be removed and cysts to be curetted and grafted are noted. (Illustration adapted from Della Valle *et al.*, 2005)

2.7 Femoral Templating

The aims of femoral templating are to achieve an implant with adequate alignment and fixation within the femoral canal to restore femoral offset and to optimize limb length. At the femoral side, Scheerlinck (2010) propose to use the medullary canal, the lesser and the greater trochanter for femoral implant templating. The shortest distance between the femur head of rotation and the longitudinal axis of the femur is defined as the femoral offset (Mcgrory 1995, Charles *et al* 2004). It is important to restore femoral offset as it controls the moment arm and tension of the abductors (Mcgrory 1995), soft tissue tension (Charles et al 2004), and acetabular component wear (Little *et al* 2009). When there is insufficient restoration of the femoral offset, this leads to excessive wear (Sakalkale *et al* 2001), limping and dislocations (Fackler *et al* 1980). On the other hand excessive restoration of femoral offset causes overloading of the femoral implant(Mcgrory *et al* 1995), micromotion generation at the bone-implant interface(O'Connor *et al* 1989), and pain in both abductors and greater trochanter (Blackley *et al* 2000).

The longitudinal axis of the implant is positioned parallel to the longitudinal axis of the femur and the approximate insertion depth is chosen in order to correctly restore the leg or hip length. Fine tuning to restore the offset and the original femoral rotation centre, can be done in three different ways, which is either by (i) medialising or lateralizing the femur by using a standard or offset stem, (ii) choosing a stem with a different neck-shaft angle or (iii) modifying the length of the femoral neck (Scheerlinck, 2010). While centered within the femoral canal, the femoral template is displaced proximally or distally to correct any lower limb length discrepancy.

In femoral templating for cemented stem, the stem should allow for a 2-mm circumferential cement mantle, which usually is marked on the template (Della Valle *et al*., 2005).

In addition to femoral offset templating, it is important to identify any existing limb length discrepancy to enable intraoperative correction. Limb length discrepancy is determined by comparing the vertical distance between proximal corner of lesser trochanter to the reference line (usually a horizontal line connecting the lower border of inferior pubic rami), on both femurs (Williamson *et al* 1978).

2.8 Utility and Accuracy of Preoperative Templating

Eggli *et al* (1998) evaluated the efficacy of preoperative planning in achieving the appropriate type and size of implant; orientation and anatomical position of the acetabular component; and restoration of leg length discrepancy in 100 consecutive primary total hip replacements performed by one experienced surgeon. The authors reported that the correct type of prosthesis was planned in 98%, and the agreement between planned and actually used components was 92% on the femoral side and 90% on the acetabular side. The mean (± SD) absolute difference between the planned and actual position of the centre of rotation of the hip was 2.5 ± 1.1 mm vertically and 4.4 ± 2.1 mm horizontally. On average, the difference in inclination of the acetabular component to preoperative plans differed by 7 ± 2° and for anteversion by 9 ± 3°. The mean postoperative leg-length difference was found to be 0.3 ± 0.1 cm clinically and 0.2 ± 0.1 cm radiologically. More than 80% of intraoperative difficulties were anticipated via preoperative planning and these includes the need for trochanteric osteotomy, acetabular autografts and allografts, acetabular reinforcement rings, and resection of osteophytes.

Della Valle *et al* (2005) reported the acetabular component size was predicted exactly in 116 hips (83%) (within 1 size in 138 hips [99%]); while the femoral component size was predicted exactly in 108 hips (78%) (within 1 size in 138 [99%]). In 75 arthroplasties (45%), the center of rotation was found to be within 2 mm of horizontal and vertical distance from the plan, and in 127 (91%) arthroplasties, it was within 4 mm. The inclination of the cup was found to average 44° (range, 30°–58°). The stem was in a neutral alignment in 122 hips (88%), varus orientation in 11 hips (8%), and in 2° of valgus oreintation in 6 hips (4%). In 103 arthroplasties with a normal contralateral hip or a THA, the average limb-length discrepancy was 1.71 mm.

Devito *et al* (2012) evaluate the efficacy of the use of templating in total hip arthroplasty in forty-three anteroposterior X-rays which were analyzed by three experienced surgeons. They analysed the sizes of the acetabular cup, as well as the stem and plug of the distal femoral canal. The study showed that templating used in preoperative planning proved effective.

Tripuraneni *et al* (2010) highlighted the importance of preoperative templating for total hip arthroplasty. They found that when there is inferior acetabular cup positioning, this leads to an error of excessive limb lengthening (P=0.036). It is also found that when there was incomplete medialisation of the acetabular component, this led to an increased offset.

2.9 Existing results on conventional versus digital preoperative templating

The *et al* (2007) studied two hundred and ten total hip arthroplasties which were randomized. Accuracy was the main outcome of this study. It was found that digital preoperative plans were more accurate in determining the actual cup size ($P < 0.05$) and scored higher on the postoperative radiologic assessment of cemented cup ($P = 0.03$) and stem ($P < 0.01$) Thus it was concluded that digital plans slightly outperform analogue plans.

Della Valle *et al* (2007) prospectively compared the precision of preoperative templating performed in printed films (analogue) with digital radiographs (digital) in 69 patients who were undergoing primary total hip replacement. The study showed that analogue preoperative planning yielded more predictable results than digital planning, particularly in terms of acetabular component size and LTCD (lesser trochanter to the centre of the prosthetic head) which shows the limb length shortening.

In Kosashvili *et al* (2009) eighteen patients with primary osteoarthritis who were undergoing uncemented total hip arthroplasty had their hip radiographs undergo digital templating and conventional templatingtechniquesn preoperatively. At separate sittings, the preoperative templating conducted independently using hard-copy radiographic films and traditional hard-copy prosthetic overlays on a radiograph view box. There was no significant difference in the performance of the 2 techniques in predicting final component selection during surgery.

Among all these studies, all of them were conducted in western countries. However, there are no studies done among the Malaysian population. Since there are contradictions in

Western studies; this study was done to highlight our experiences. Our centre is one of the designated centres in the country for arthroplasty fellowship.

CHAPTER 3: OBJECTIVES AND HYPOTHESIS

3.1 Objectives

3.1.1 General Objective

To compare the accuracy of conventional templating techniques and digital templating system in primary total hip arthroplasty at Hospital Sultanah Bahiyah Alor Setar, Kedah, Malaysia

3.1.2 Specific Objectives

1. To determine the difference of acetabular cup size in primary total hip arthroplasty between conventional templates and digital templates from actual implant.
2. To determine the difference of femoral stem size in primary total hip arthroplasty between conventional templates and digital templates from actual implant.
3. To determine the agreement between conventional templates and actual implant in determining the acetabular cup size and femoral stem size
4. To determine the agreement between digital templates and actual implant in determining the acetabular cup size and femoral stem size
5. To determine the mean absolute errors of acetabular cup size and femoral stem size for conventional templating and digital templating as compared to actual implant.

3.2 Hypothesis Statements

1. There are no significant differences of acetabular cup size in primary total hip arthroplasty between conventional templates and digital templates from actual implant.

2. There are no significant differences of femoral stem size in primary total hip arthroplasty between conventional templates and digital templates from actual implant.

3. There is a significant agreement between conventional templates and actual implant in determining the acetabular cup size and femoral stem size

4. There is a significant agreement between digital templates and actual implant in determining the acetabular cup size and femoral stem size

5. The mean absolute errors of acetabular cup size and femoral stem size does not significantly differ for conventional templating and actual implant.

6. The mean absolute errors of acetabular cup size and femoral stem size does not significantly differ for digital templating and actual implant.

CHAPTER 4: METHODOLOGY

4.1 Study Design

Retrospective study

4.2 Target Population

All patients that underwent primary total hip arthroplasty for osteoarthritis, avascular necrosis of femoral head and femoral neck fracture in Hospital Sultanah Bahiyah Alor Setar

4.3 Sampling Frame

All patients that underwent primary total hip arthroplasty in Hospital Sultanah Bahiyah Alor Setar from June 2011- June 2014

4.4 Sampling Method

Purposive sampling - All patients that underwent primary total hip arthroplasty for osteoarthritis, avascular necrosis of femoral head and femoral neck fracture in Hospital Sultanah Bahiyah Alor Setar from June 2011- June 2014 that fulfilled the inclusion and exclusion criteria were included in this study

4.5 Sample Size Estimation

Sample size estimation was performed using power and sample size calculations software (version 3.0.12, Dupont, 1990). Previous studies data indicate that the exact size for digital and conventional are 61% and 33% respectively. The study needs 49 patients per group to be able to reject the null hypothesis with probability (power) 0.8. The Type I error probability associated with this test of this null hypothesis is 0.05. Paired t-test statistic is used to evaluate the null hypothesis. With an additional of 20% dropout rate, the total sample size is 61 samples per group.

4.6 Selection Criteria

4.6.1 Inclusion Criteria

- Patient indicated for primary total hip arthroplasty in condition as follows;
    - Osteoarthritis
    - Avascular necrosis of femoral head
    - Femoral neck fracture

4.6.2 Exclusion Criteria

- Patients who had history of previous fracture or operation at the affected proximal femur and acetabular
- Patients who required a complex surgical procedure such as extensive bone grafting and osteotomy

4.7 Research Tool and Data Collection

1. Preoperative anteroposterior view of the pelvis and affected hip radiograph is collected.
2. Radiograph standardization:

- Pelvic x-ray: Low AP pelvic radiograph with x-ray beam centered just below the pubic symphysis. Both hip were internally rotated 10 to 15^{o} to compensate for the physiologic anteversion.
- Visualization of proximal third of the femur was necessary for full femoral stem templating.
- Radiograph magnification factor: x-ray source to image and x-ray source to object distances were fixed with an average magnification of 120% for both conventional and computerized radiograph imaging

- Calibration objects (metal sphere) were position at level of hip joint in the anteroposterior plane, in order to be less dependent on an accurate radiographic set up

3. Templating landmark: (Figure 2.3)

- Acetabular component:
    - Acetabular " tear drop"
    - Ilio-ischial line
    - Acetabular roof (superolateral margin of the acetabulum)
- Femoral component:
    - Medullary canal
    - Lesser and greater trochanter

4. Acetabular position in templating

    - A horizontal reference line draw through the base of the teardrops
    - Superimpose the cup templates on the radiograph
    - An inclination angle of approximate 40- 45 degree
    - Inferior aspect of acetabular component is level with the base of teardrop
    - The superior margin is covered by the superolateral acetabulum
    - The medial aspect approximate the ilio-ischial line/ Kohler's line