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ORIGINAL STUDY

Digital templating facilitates accurate leg length correction in total hip arthroplasty

Shivan Sabah JASSIM, Christopher INGHAM, Matthew KEELING, James Anthony WIMHURST

From the Norfolk and Norwich University Hospital NHS Foundation Trust, Norwich, Norfolk, UK

Digital templating of pre-operative radiographs is increasingly utilised by surgeons before total hip arthroplasty (THA) as part of an adequate pre-operative preparation to minimise complications. Templating can accurately predict the required implant sizes but its use in facilitating correction of leg length discrepancy (LLD) has been under-reported in the literature.

We performed a retrospective analysis of a cohort of consecutive patients undergoing primary THA. A comparison was made of the implant sizes templated with actual sizes used. In addition, pre-operative leg-length discrepancy (LLD) was noted and compared with intra-operative measurement of LLD correction and post-operative LLD correction seen on post-operative radiographs, as measured by two independent observers. Statistical analysis was performed to investigate the correlation between pre- and post-operative measurements.

Fifty nine patients that had primary THA were investigated, 42 with hybrid replacements, 17 with cemented replacements. Spearman's-rho 2-tailed correlation between templated and implanted femoral offset, stem size and acetabular cup size was 0.850, 0.709 and 0.834 respectively ($p < 0.01$ for all). Correlation between the pre-operative templated LLD and the measured post-operative corrected LLD was 0.841 ($p < 0.01$). No difference existed between hybrid and cemented hips or the presence or absence of a contralateral hip replacement.

In this study, templating for THA was significantly accurate in predicting the required femoral and acetabular implant sizes. In addition, the correction of pre-operative LLD was accurately performed, as evidenced by measurement on post-operative films. The results of this study support the pre-operative digital templating of radiographs in total hip arthroplasty.

Keywords : hip arthroplasty ; templating ; leg length correction.

INTRODUCTION

Total hip arthroplasty is one of the most common elective orthopaedic operations in the UK with over 65,000 procedures performed in the past year (*16*). Best practice for any surgical procedure is to be well prepared to anticipate potential intraoperative pitfalls and manage them expediently. In the pursuit of efficient preoperative planning, digital templating of pelvic radiographs has emerged as a useful tool for surgeons to predict the required femoral

■ Shivan Jassim, MRCS, Orthopaedic Trainee.
■ Christopher Ingham, FRCS, Orthopaedic Surgeon.
■ Matthew Keeling, BSc, Data Analyst.
■ James Wimhurst, FRCS, Orthopaedic Surgeon.
Department of Trauma & Orthopaedics, The Norfolk and Norwich University Hospital NHS Foundation Trust, Norwich, Norfolk, UK.
Correspondence : Shivan Jassim, Department of Trauma & Orthopaedics, The Norfolk and Norwich University Hospital NHS Foundation Trust, Colney Lane, Norwich, Norfolk NR4 7UY. E-mail : shivan.jassim@doctors.org.uk

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stem and acetabular cup sizes for each patient (*10*). Knowledge of the correct implant sizes has several advantages. In addition to being able to record the most popular sizes for the department's inventory service, templating allows the operating surgeon to optimise the stability of the joint, construct and correct femoral offset and leg length discrepancies that may have developed secondary to joint disease.

Existing studies have assessed the accuracy and benefits of pre-operative templating. Eggli *et al* demonstrated 90% agreement between templated and implanted cup sizes and 92% for cemented femoral stem sizes (*10*). Knight and Atwater showed agreement in 78% of cemented stems and 42% in cementless stems (*8*) ; this paper noted that undersizing of the stem occurred in 50% of cases relative to the template measurements. However, there has been little in the literature speculating on the value of templating in the correction of leg length discrepancy (LLD). The importance of LLD following total hip arthroplasty is well documented and inadequate correction has been associated with dislocation of the hip, gait disorders and general dissatisfaction with the procedure (*9*).

In our practice, digital templating is used for all primary hip arthroplasty to predict the required implant sizes and also to plan restoration of leg length. The aim of this study was to analyse the accuracy at which implant sizes are predicted by templating and also at how accurate templating can be in facilitating the correction of LLD.

PATIENTS AND METHODS

A consecutive list of patients who had undergone primary arthroplasty was obtained from the logbook of the lead surgeon over a period of one year. Any revision arthroplasties or patients having conversion to total hip replacement from previous metalwork were excluded from the study. From this patient list, measurements from the pre-operative radiographs that had been analysed and stored in the hospital Patient Archiving Communication System (PACS) (Centricity, GE Medical Systems, Wallingford, Connecticut) were performed using the templating software OrthoView™ (Southampton, England) were taken (*17*) (Fig. 1). This included the predicted femoral stem and offset sizes, acetabular cup size and leg length discrepancy. Magnification of pre-operative films was assessed by the method described by Heinart *et al* (*5*).

The operative notes for each of these patients were obtained. The choice of prosthesis and cup combination and sizes of femoral and acetabular implants were noted. At the time of surgery, which was performed via a posterior approach in the lateral decubitus position, the operating surgeon (JAW or supervised registrar) inserted a Charnley pin into the supra-acetabular ilium prior to dislocation of the hip. Using a coagulation diathermy, a 1cm mark was made at the vastus ridge of the proximal femur and the distance from the pin to this mark measured with a steel ruler, with the knees and ankles of the patient opposed. The approach was then completed and the hip dislocated. After insertion of the acetabular component, trial reductions were performed with the final femoral broach and head trials with varying neck length. The depth of broach insertion and choice of neck length was used to achieve the pre-operatively planned leg length correction as accurately as possible without compromising stability. The definitive femoral component was then inserted to the planned depth before a final trial reduction allowing fine tuning of neck length. All patients received a cemented Exeter stem and either a cemented Contemporary Cup or cementless Trident Cup (all Stryker, Newbury, UK) or cementless Reflection Cup (Smith & Nephew, Warwick, UK) (Fig. 2).

The post-operative radiographs on the hospital PACS were independently scrutinised by two authors not involved in the primary operation (SJ and CI) to measure the subsequent leg-length changes. This was done by measuring the distance between the interteardrop line and mid-point of the lesser trochanter on each leg and recording the difference. Adjustments were then made according to the magnification factor of these radiographs, judged from the size of the femoral head. All results were collated and analysed by an independent statistician (MK) using SPSS software (version 19, IBM, Chicago, USA). Statistical analysis using Q-Q plots and the Shapiro-Wilk test demonstrated that the collected data was not normally distributed. Therefore Spearman's-rho co-efficient was used to analyse results to investigate correlation.

RESULTS

Sixty-one consecutive patients had primary hip arthroplasty by a single experienced consultant surgeon or specialist registrar under direct supervision. Two of these were excluded on the basis of

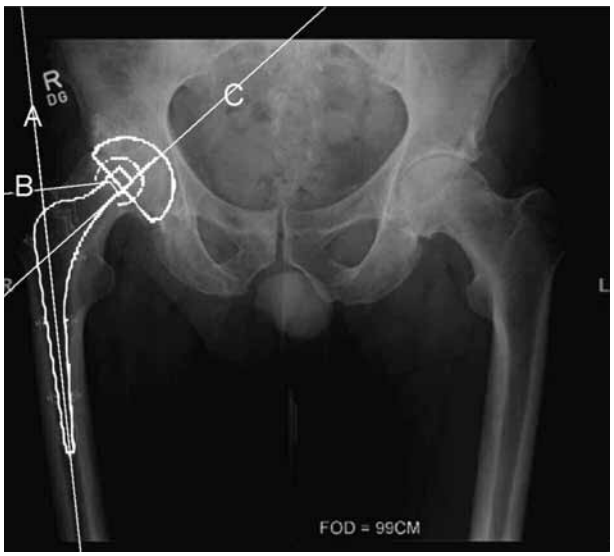

Fig. 1. — Pre-operative templating radiograph of patient for total hip replacement with significant leg length discrepancy (LLD). Vertical line A represents femoral alignment, perpendicular line B indicates head centre in relation to greater trochanter. Intersection of lines A & C gives neck-shaft angle. FOD – Field of depth.

having previous metalwork *in situ* from previous operations for trauma and SUFE respectively. Of the remaining 59 operations, 42 were hybrid operations, 17 were cemented hips. Ten patients had a hip replacement on the contralateral side whilst 49 patients were having their first arthroplasty.

For 59 patients, Spearman's-rho 2-tailed correlation for the templated and re-created femoral offset was 0.850 ($p < 0.01$). An exact match occurred in 51 (86%) cases, with over-sizing in 5 (9%) and under-sizing in 3 (5%) (Table I). For the size of femoral implant templated and used, correlation was 0.709 ($p < 0.01$). An exact match occurred in 37 (64%) cases, with over-sizing in 11 (18%) and under-sizing in 11 (18%) (Table II). For the size of acetabular component templated and used, correlation was 0.834 ($p < 0.01$). An exact match occurred in 28 (47%) cases, with over-sizing in 18 (31%) and under-sizing in 13 (22%) (Table III)]. Spearman's-rho 2-tailed correlation for the templated LLD and the corrected operative LLD was -0.607 ($p < 0.01$) (Fig. 3). Between the templated LLD and the measured LLD on post-operative film, taken as a mean between the two observers, correlation was 0.841

Fig. 2. — Post-operative radiograph of same patient as in Figure 1 with correction of LLD.

Table I. — Comparison of numbers of templated and actually implanted femoral offset sizes

Femoral Offset	Templated	Implanted
37.5	16	14
44	32	38
50	11	7

Table II. — Comparison of numbers of templated and actually implanted femoral implant sizes

Femoral Size	Templated	Implanted
0	24	20
1	14	23
2	16	10
3	5	3
4	0	3

($p > 0.01$) (Fig. 4). Agreement of measurements between the first and second observers was correlated at 0.997 ($p < 0.01$)

No difference was seen on the basis of the type of hip replacement or whether or not a contralateral hip replacement was *in situ* ; all subgroups had statistically significant correlation between templated and used implant sizes and correction of templated and measured LLD.

Table III. — Comparison of number of templated and actually implanted acetabular cup sizes

Acetabular Cup Size (mm)	**Templated**	**Implanted**
42	1	0
44	0	0
46	1	1
48	11	9
50	11	14
52	10	13
54	6	7
56	12	8
58	4	4
60	3	2
62	0	1

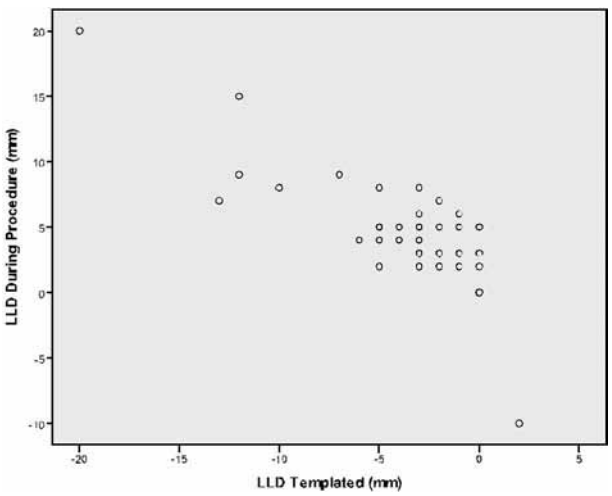

Fig. 3. — Scatterplot graph showing correlation between pre-operative templated LLD and LLD corrected during operation (measured with Charnley pin in supra-acetabular ileum).

DISCUSSION

Fifty-nine patients undergoing primary hip arthroplasty had their pre-operative pelvic radio - graphs templated to predict the size of femoral implant, femoral offset and acetabular cup that was required. They also had measurement of their pre-operative LLD.

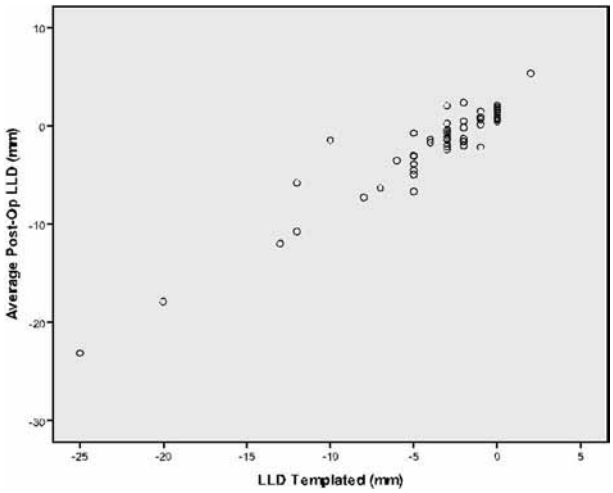

Fig. 4. — Scatterplot graph showing correlation between pre-operative templated LLD and post-operative LLD, taken as the mean measurement of the two observers.

Patients with revision of previous metal work were excluded from the study because of the distorted joint measurements that would have been grossly altered due to the abnormal joint architecture from previous surgery rather than primary osteoarthritis.

This study showed that the size of implants templated and used showed correlation with statistical significance. In addition, the operative correction of LLD and post-operative radiograph interpretation of LLD correction also correlated with pre-operative images to a statistically significant degree.

For the type of hip replacement, correlation between femoral and acetabular implant sizes templated and used was statistically significant for both hybrid and cemented hips.

The presence or absence of a contralateral hip replacement made no difference to outcome, with both subsets showing a statistically significant correlation for implant sizes, offset creation and LLD correction.

The type of acetabular cup had no bearing on the correlation between templated and used femoral and acetabular implant sizes, with all types showing a statistically significant agreement.

Our results compare favourably with other studies investigating correlation between templated and

used implants in joint arthroplasty. Digital templating for total hip replacements has been shown to be as effective in predicting implant sizes as traditional hard-copy prosthetic overlays (*6,10*). Gamble *et al* demonstrated that digital templating was more accurate in predicting acetabular sizes in comparison to hard-copy overlays (*4*). Prediction of implant sizes with digital templating has been shown to have high accuracy in uncemented total hip arthroplasty (*11*) and total knee arthroplasty (*12*) with little intraobserver and interobserver variation.

However, none of these studies have explicitly evaluated the benefit of templating on predicting the correction of LLD ; we believe that ours is the first study that does so.

Leg length discrepancy is a significant problem in total hip arthroplasty. Although it may not be possible to eliminate it completely, minimisation is key to avoid complications such as sciatic nerve palsy (*13*). LLD is also a strong indication for revision hip surgery due to functional impairment (*18*). In addition, it has been demonstrated that post-operative LLD is a significant cause of litigation claims in the NHS (*14*). This study demonstrates that both pre-operative templating of LLD and intra-operative measurement of LLD correction using an iliac pin as a fixed point significantly correlate with the correction of LLD as demonstrated on post-operative radiographs. Measurement of LLD on post-operative radiographs has been shown to have good accuracy (*7*). The method used to measure LLD on radiographs by our authors is similar to that of several other studies (*15*), with referencing from the interteardrop line and the lesser trochanter.

Limitations to the study were that not all radiographs were taken at the same intervals prior to operation, thus any interval alterations in pelvic architecture and LLD would not have been taken into account, although this is unlikely to have had a significant influence over measurements.

The calibration of radiographs to allow for different magnification factors has been shown to be important in facilitating accurate measurements in digital templating (*3*). Twenty-eight of the patients did not have a recorded magnification value on the pre-operative templating film. In these hips, the magnification was estimated at 116%, the mean magnification factor of all pelvic films that have their magnification recorded in our hospital. However, removal of these hips from the study did not have any alteration on the statistical significance of any of the measured parameters.

In conclusion, digital templating of pre-operative radiographs for hip arthroplasty is a useful tool that significantly correlates with operative practice in selecting the correct implant sizes, re-creation of femoral offset and correction of LLD.

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