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ORIGINAL PAPER

Radiographic templating of total hip arthroplasty for femoral neck fractures

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Abstract
Purpose The purpose of this study was to evaluate the use of pre-operative digital templating to minimize complications including limb length discrepancy (LLD), intraoperative fractures and early dislocations in patients with intracapsular femoral neck fractures.
Methods We retrospectively compared 23 patients undergoing total hip arthroplasty (THA) for intracapsular femoral fractures with pre-operative digital templating and 48 patients without templating.
Results The mean post-operative LLD was significantly lower in patients who had pre-operative templating than in the control group (6.7 vs. 11.5 mm, $p = 0.023$). Only three patients (13 %) with templating had LLD greater than 1.5 cm, compared to the 15 patients (31 %) without templating ($p = 0.17$). In eight cases the final femoral stem size matched the templated size, while 19 patients were within two size increments. Complications included one dislocation and one intraoperative fracture in the control group.
Conclusion The present study demonstrated that careful pre-operative planning may reduce LLD in patients undergoing THA due to intracapsular hip fractures.

Keywords Femoral neck fracture · Total hip arthroplasty · Leg length discrepancy · Pre-operative planning · Templating

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Introduction

The purpose of pre-operative planning in patients undergoing total hip arthroplasty (THA) is to evaluate the anatomy of the hip, choose appropriate implant design, assess implant size and plan implant positioning in order to achieve optimal joint kinematics, including centre of rotation, offset and limb length [1–3]. Numerous studies discuss the optimization of implant size while few address limb length through pre-operative templating [1, 2, 4–22]. Despite templating being common practice and highly recommended by many authors and all implant manufacturers, there are no comparative studies demonstrating its benefit.

The treatment of displaced intracapsular fractures of the femoral neck with total hip arthroplasty has been consistently reported to have superior functional outcome over hemiarthroplasty in ambulatory patients and is progressively becoming the recommended treatment by many surgeons [23–27]. The traditional concern about high dislocation rates is changing with modern reports of lower and acceptable figures with evolving techniques and implants [23–26, 28]. While performing a THA on a recently healthy hip joint with no limitations in pre-injury range of motion nor soft tissue contractures, meticulous pre-operative planning is needed to optimize implant positioning and joint stability. Unlike THA for a degenerative joint, the use of fixed reference points such as the iliac fixation pins to measure limb lengthening is impracticable in the trauma setting due to significant displacement and bony deformation. The surgeon may rely only on less accurate or cumbersome techniques including soft tissue tension tests, use of the contralateral leg as a reference or intraoperative radiographs [29, 30]. Proper pre-operative planning is therefore essential. Challenges related to pre-operative planning for the fractured hip include potential difficulties in obtaining quality radiographs in patients limited by the pain of

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their injury and the use of the contralateral hip for templating. Pre-operative assessment of implant size has the potential to lower the risk of intra-operative fractures of osteoporotic bone.

Apart from a minor mention in a paper by Della Valle [19], no data is currently available in the English literature regarding pre-operative planning of THA for fractures. Additionally, no comparative studies were published describing the influence of pre-operative planning on LLD neither in trauma nor degenerative cases. The purpose of this study was to evaluate the influence of pre-operative templating on complications including LLD, intra-operative fractures and early dislocations in patients with intracapsular femoral fractures.

Patients and methods

This is a retrospective comparison between patients undergoing THA for intracapsular femoral fractures with and without pre-operative digital templating. Between January 2009 and August 2012, 193 patients underwent hip arthroplasty secondary to a femoral neck fracture at our institution: Seventy five had THA and 118 had hemiarthroplasties. The study group included the patient population treated since the inception of routine templating of THA for fractures on February 2011. Patients with pre-existing and/or contralateral native hip deformity or prior hip surgery were excluded. Twenty three consecutive patients (18 females) with the mean age of 72 (range, 57–88) were included. Two patients were excluded due to a contralateral THA. The control group included patients treated between January 2009 and January 2011, a period in which templating was absent in the setting of hip fractures. Forty eight consecutive patients (26 females) with the mean age of 75 (range, 53–93) were included. Two patients were excluded due to contralateral THA. There were no significant differences between the groups regarding age and gender.

All patients underwent digital radiography using a standard protocol, including antero-posterior (AP) view of the pelvis. The pelvic AP views were taken with the patient supine, with the beam centered over the pubis symphysis. Ideally both hips were internally rotated 10 to 15° to balance physiologic anteversion, however this was difficult to achieve in the fractured hip. In the study group, a 1-inch calibration metal ball was placed close to and at the level of the greater trochanter (Fig. 1a) [9, 31]. Routine pre-operative planning was performed by the surgeon using TraumaCad® (TraumaCad, Petach-Tikva, Israel). Templating was performed on the contralateral side. Templating began with marking a horizontal reference line tangential to the inferior point of bilateral ischium (Fig. 1b). It was assumed that the patient had no pre-injury LLD and aimed to preserve length and offset as determined by the uninjured limb. The superolateral acetabular margin, the teardrop, the ilioischial line and the centre of rotation are identified. The cup template is positioned and sized to maintain the

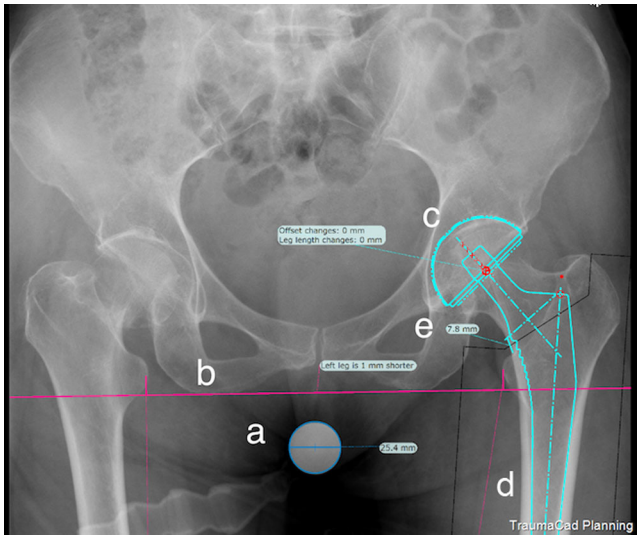

Fig. 1 Pre-operative planning. **a** One-inch calibration metal ball. **b** Horizontal reference line. **c** Cup template. **d** Stem template. **e** Marking of the desired neck cut

native centre of rotation while removing a minimal margin of subchondral bone with complete coverage at 45° of inclination relative to the horizontal (Fig. 1c). Appropriate stem size and position is selected to achieve adequate fit in the canal while maintaining the native length and offset (femoral neck tip overlapped with the acetabular centre of rotation; Fig. 1d). The desired neck cut is measured (Fig. 1e).

All patients were operated through the lateral transgluteal approach by one of three fellowship trained arthroplasty surgeons. A ruler was used to mark the planned neck cut level as measured from the top of the lesser trochanter, as pre-operatively planned. The cementless Corail stems and Pinnacle cups (Depuy, Warsaw, Indiana) were utilized.

AP pelvic radiographs were routinely performed two days post-operatively (Fig. 2). The prosthetic femoral head was used

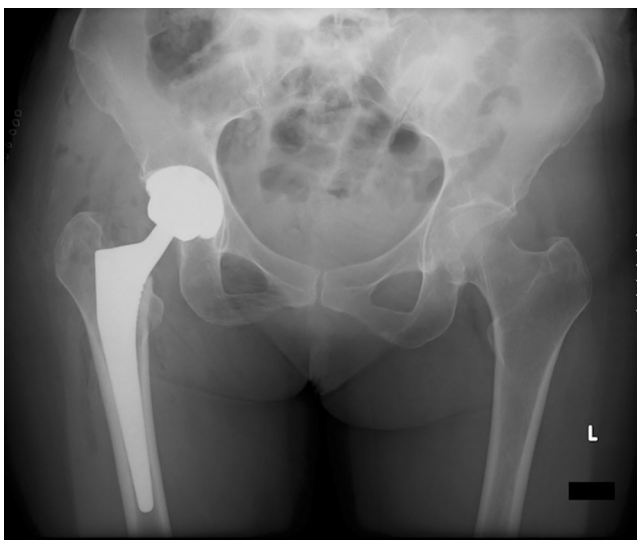

Fig. 2 Immediate post-operative radiograph

for post-operative radiographic calibration. LLD was measured digitally via TraumaCad® software by two authors (IB, EA) blinded to the patient cohort. In case of inter-observer discrepancies greater than 2 mm in two separate measurements, it was repeated together with the equally blinded senior author (RD) until consensus was achieved; LLD measurements were based on perpendicular vertical measurements from the horizontal reference to the tip of the lesser trochanter [32]. Operative reports and patient hospital charts were reviewed for intra and post-operative complications. Intra-operative periprosthetic fractures, joint dislocations and further complications during a follow-up period of 13–56 months (mean, 33) were recorded.

Data was collected using Microsoft Excel spreadsheet, and later processed with SPSS 20 (SPSS, Chicago, IL, USA). Patients' ages and LLD were compared using the two-tailed Student's *t*-test. Patient genders, rates of dislocations and intra-operative fractures were compared using the chi-square test. A P value of < 0.05 was considered significant.

Results

Demographic and clinical details of the two groups are summarized in Table 1.

Within the group of patients having received templating, the templated and used femoral component matched in eight of the cases. In seven patients the difference was 1 size, while in four patients it was 2 sizes and in four other patients, the discrepancy was 3 sizes.

Mean post-operative LLD was significantly lower in patients who had pre-operative templating than in the control group (6.7 mm vs. 11.5 mm, $p = 0.023$). Five patients (21 %) with templating and 28 (41 %) patients without templating had limb-length discrepancy of 1 cm or more ($p = 0.051$). Only three patients (13 %) with templating had LLD of more than 1.5 cm, compared to 15 patients (31 %) without templating ($p = 0.17$).

There was one case of intra-operative femoral cracking and one case of early dislocation in the non-templated group. The dislocated hip was revised. There was one case of superficial infection in each group, treated successfully with antibiotics.

Discussion

Restoration of hip kinematics, including anteversion, length and offset is always a challenge in THA (Fig. 3) [33]. Pre-operative planning is considered essential for the success of elective THA [34]. Such planning includes both clinical and radiographic assessments, measurements and templating. With the current trend of expanding the indications for THA in patients with femoral neck fractures, it is important to understand the significance and limitations associated with pre-operative templating and leg-length restoration in a different patient population. Although pre-operative planning and templating is considered a standard of care at the present, the literature is scarce with studies addressing its effect on post-operative LLD. The efficacy of pre-operative planning in patients undergoing THA for hip fractures is not yet known. The present study demonstrated that careful pre-operative templating may reduce LLD in patients with intracapsular femoral neck fractures and is reasonably accurate in predicting stem size.

This study has several limitations. First, this is a retrospective study with an historic control group. Consequently, the follow-up periods of the compared groups do not overlap. However, the assessment of post-operative LLD, intra-operative fractures and implant size prediction are not dependent on the length of follow-up. Furthermore, most post-operative dislocations related to implant positioning would have expected to occur by the 13 months of our minimal follow-up. Second, the series is underpowered to differentiate rates of intra-operative fractures and post-operative instability.

Restoration of LLD in patients with hip fractures is challenging. Pre and intra-operative leg length assessment is difficult because the anatomy is distorted by the fracture [35]. However, patients' expectations are generally higher since these patients usually had normally functioning hip pre-injury. Since stability is always a concern when performing THA for fractures, a less experienced surgeon might tend to lengthen the limb, even more so than in the setting of a degenerative joint. One of the difficulties lies in the inability to use the ilium as a reference to assess limb length, since the

Table 1 Demographic and clinical details of the patients

Parameter	Templating group ($n = 23$)	Control group ($n = 48$)	*P*-value
Mean age	72	75	0.26
Gender F:M	18:5	26:22	0.06
Mean follow-up	19 months	40 months	0.0001>
Mean LLD (range)	6.7 mm (0–21)	11.5 mm (0–31)	0.023
LLD more than 1 cm	5 (21 %)	28 (41 %)	0.051
Dislocations	0	1	0.48
Intraoperative fractures	0	1	0.48

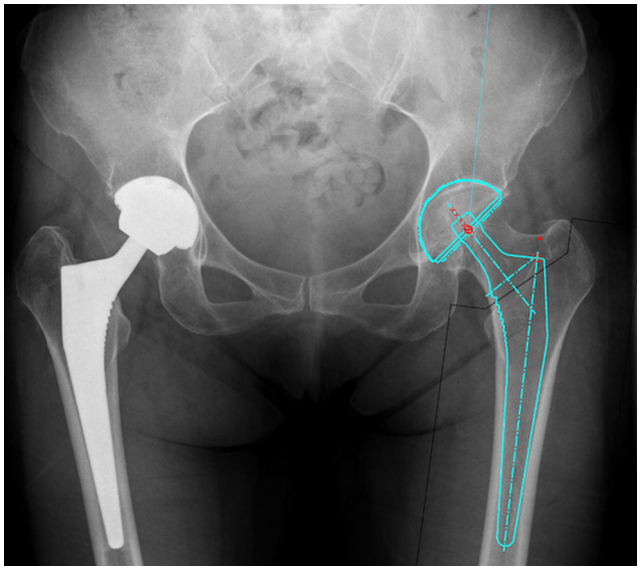

Fig. 3 One-year post-operative radiograph. The non-injured side was templated for demonstration

pre-operative position of the femur relative to the ilium is altered by the fracture. Since the other aforementioned intra-operative techniques for assessment of leg length are more subjective and experience related, it is advisable to perform systematic pre-operative planning with determination of cup positioning and center of rotation, and determination of the appropriate level of femoral neck cut and implant offset.

Della Valle et al. used hard copy pre-operative templating in 139 THAs. Twenty two of his patients had femoral neck fractures as the indication for surgery. Post-operative mean LLD in this group was 3.27 mm (range, −3 to 8 mm) [19]. The authors advocated considering 3–6 mm of intentional overlengthening in order to facilitate joint stability. Table 2 compares other studies reporting LLD measurements after templated THA in the elective setting. Differences between reports are multifactorial and include factors like surgeon experience, philosophy (length vs. stability), choice of implant and the minimal inter-observer measurement bias with radiographic LLD determination. Since none of these reports were comparative, it is difficult to assess the role of templating in leg-length restoration.

Our results regarding LLD were less favourable than the other reports. However, a significant improvement in post-operative LLD was achieved with the introduction of pre-operative templating. Two major differences may account for our reported higher incidence of LLD compared to the cited references. Firstly, our patient population included only femoral neck fractures as the indication for THA rather than arthritis. With a higher concern about stability in such patients, surgeons may have the tendency to "go on the safe side" and lengthen the limb for the sake of stability. There was one dislocation (1.4 %) between both cohorts and no dislocations within the templated group. Secondly, in most other studies listed in Table 2, LLD was manually measured on non calibrated hardcopy radiographs, assuming 20 % magnification. Only in the study of Bertz et al. [7], radiographs were digitally calibrated via a calibration ball and the mean LLD was comparable to the results of this study.

The ability to accurately predict stem size with templating is limited. Previous studies showed only 32–80 % of accuracy in predicting stem size [1, 2, 4, 6–10, 12–14, 16, 17, 19–22]. This study showed a match rate of 35 %. The limited accuracy of femoral component determination may result from differences in patients' body habitus and variations in the femoral anatomy [3, 10]. However, accuracy of stem size prediction increased to 77–100 % when the adjacent 1 or 2 size increments were accepted. In our study, 82 % of stems were within two sizes. Nevertheless, there are significant benefits for templating for size. Predicting extreme sizes, either small or large, assists with ensuring implant availability. Additionally, when the broach size difference is greater than 2 compared to that of the predicted stem, it can alert the surgeon to assess intra-operatively for malpositioning, fracture or perforation.

Table 2 Results of different series evaluating LLD with and without templating

Study	Patients (N)	With templating		Without templating	
		Mean LLD	LLD < 10 mm	Mean LLD	LLD < 10 mm
Eggli et al. [1]	100	3 ± 1 mm	N/A	N/A	N/A
Woolson et al. [5]	351	1 ± 4.7 mm	97 %	N/A	N/A
Bertz et al. [7]	129	5 ± 4.5 mm	N/A	N/A	N/A
Unnanuntana et al. [17]	109	0.9 ± 6.8 mm	93.5 %	N/A	N/A
Hofmann et al. [18]	86	0.3 ± 2.6 mm	100 %	N/A	N/A
Della Valle et al. [19]	81	2.8 ± 4.6 mm	100 %	N/A	N/A
Present study	71	6.7 ± 7 mm	79 %	11.5 ± 8 mm	59 %

Conclusions

The present study demonstrates that careful pre-operative templating may reduce LLD in patients undergoing THA secondary to femoral neck fractures. The accuracy of femoral stem size templating in the trauma setting is comparable to the elective setting. Without other reliable measures of limb length, pre-operative planning may encourage the surgeon, when hip stability is paramount, to consider adjusting other variables including offset, version or choice of implant apart from inappropriately and knowingly lengthening the leg.

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